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Antelope Valley, California

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This report presents the results of a full scale demonstration project to confirm previous pilot studies and research done on the economics and feasibility of reclaiming wastewater for use at an aquatic park in a semi-arid area. The demonstration project included: (1) The construction of a 1900 m^3/day (0.5 mgd) tertiary wastewater treatment plant and a 22.7 ha (56 acre) park with recreational support facilities; and (2) The evaluation of the treatment system performance and the characteristics of the lake waters as they relate to chemical, physical, and biological quality, algal growth, plant growth, fish pathology, soil reclamation, and irrigation.

The completed recreational park, officially named Apollo County Park after the Apollo 11 Capsule, attests of the economic benefits and social acceptability of wastewater renovation. The evaluation studies showed that tertiary treated water is pathogenically safe, esthetically pleasing, suitable for fish life and aquatic sports, and acceptable for irrigational use.

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WASTEWATER RECLAMATION PROJECT
Antelope Valley, California

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The Municipal Environmental Research Laboratory contributes to this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

The study described here was undertaken to demonstrate the reuse of municipal wastewater as a means of conserving valuable water resources in a water-short semi-arid area by providing the public with a much needed recreational aquatic park.

Louis W. Lefke
Acting Director
Municipal Environmental
Research Laboratory

ABSTRACT

This report presents the results of a full scale demonstration project to confirm previous pilot studies and research done on the economics and feasibility of reclaiming wastewater for use at an aquatic park in a semi-arid area.

The demonstration project included: (1) The construction of a 1900 m^3/day (0.5 mgd) tertiary wastewater treatment plant and a 22.7 ha (56-acre) park with recreational support facilities; and (2) The evaluation of the treatment system performance and the characteristics of the lake waters as they relate to chemical, physical and biological quality, algal growth, plant growth, fish pathology, soil reclamation and irrigation.

The completed recreational park, officially named Apollo County Park after the Apollo 11 Capsule, attests to the economic benefits and social acceptability of wastewater renovation. The evaluation studies showed that tertiary treated water is pathogenically safe, esthetically pleasing, and suitable for fish life and aquatic sports, and acceptable for irrigational use.

This report was submitted in fulfillment of Grants Nos. 17080 GCI and WRD 97-01-68 by the County of Los Angeles, California, under the sponsorship of the U.S. Environmental Protection Agency. Work was completed in December 1973.

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SECTION I
CONCLUSIONS

TERTIARY TREATMENT PLANT

A tertiary wastewater treatment process involving flocculation with alum, sedimentation, filtration, and disinfection has been successfully put into operation to serve the Apollo Park recreational lakes near Lancaster, California (Figures 1 and 2). The capacity of this treatment plant is 1900 m^3/day (0.5 mgd). A special testing and demonstration program for this plant has shown that an effluent can be produced that meets all water quality requirements. In terms of operational costs, the cost of the effluent is comparable to the cost of California Water Project water.

The treatment plant testing program developed information on the relationships between optimal plant performance and operational parameters, and showed that alum sludge recycled through the primary treatment plant and sludge digesters had no adverse effect on these processes.

APOLLO COUNTY PARK

Apollo County Park was constructed for the use of the reclaimed water. This is a 22.7 ha (56 acre) park with a total lake surface area of 10.5 ha (26 acres) (Figure 3). The reclaimed water is used to fill the lakes, for park irrigation and for fire protection at the park and at the adjacent County airport.

The demonstration program for this park has shown that this wastewater reclamation and reuse concept can be successfully applied for aquatic recreational facilities in spite of difficulties caused by adverse soil conditions and high evaporative water losses. The water quality is also

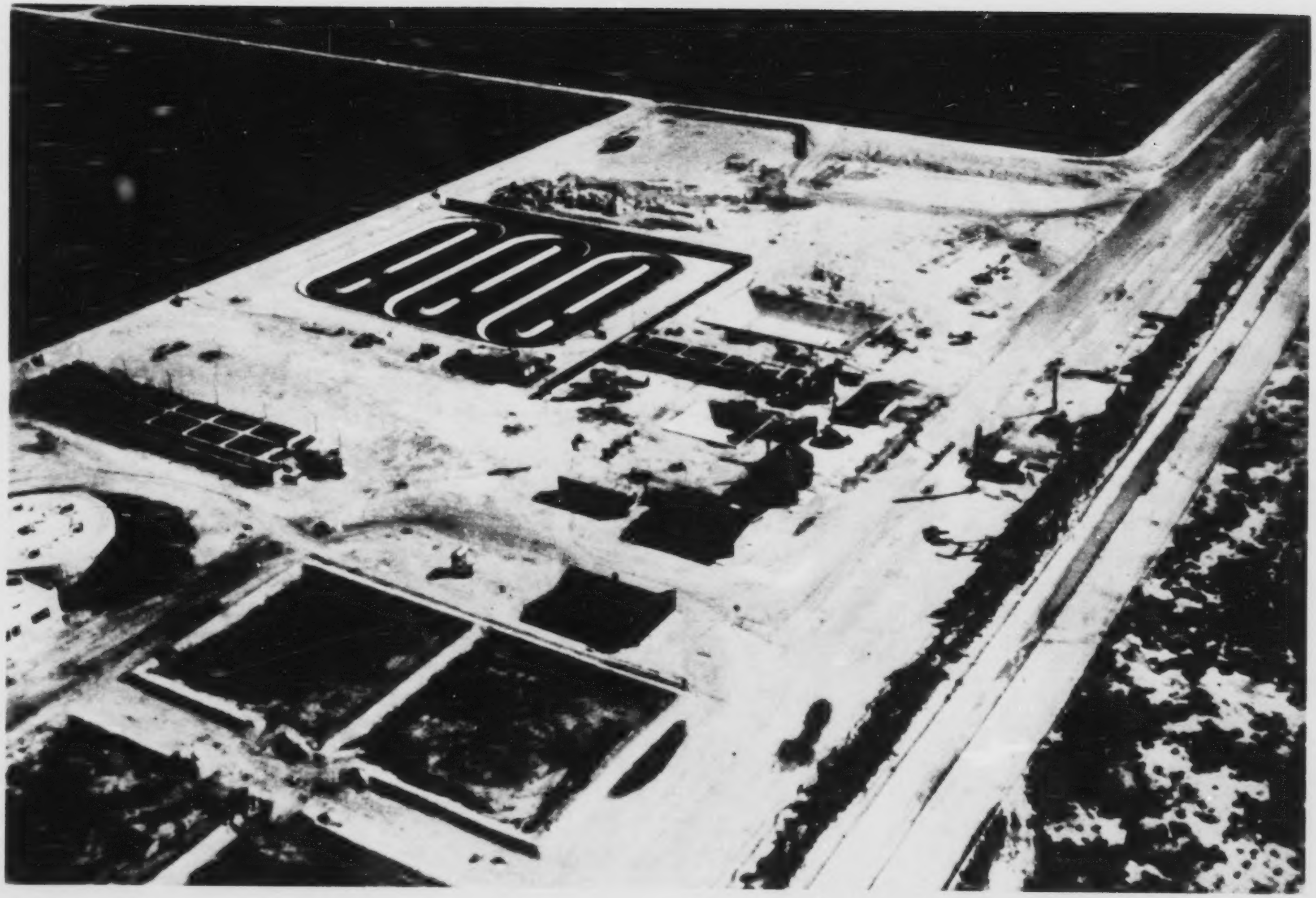


Figure 1 WATER RENOVATION PLANT
LOS ANGELES COUNTY SANITATION DISTRICT NO. 14

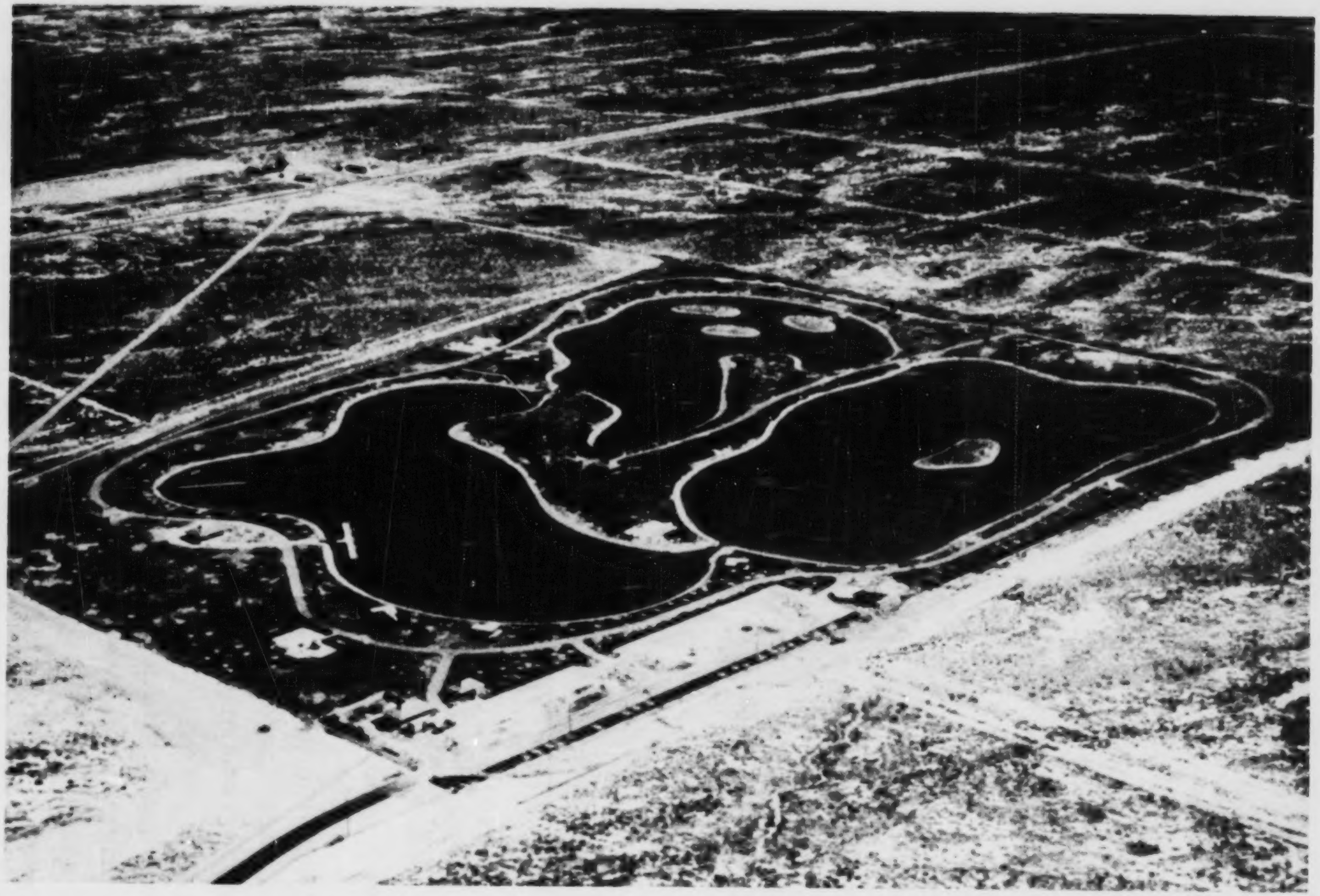


Figure 2 APOLLO COUNTY PARK
UTILIZING RENOVATED WASTEWATER

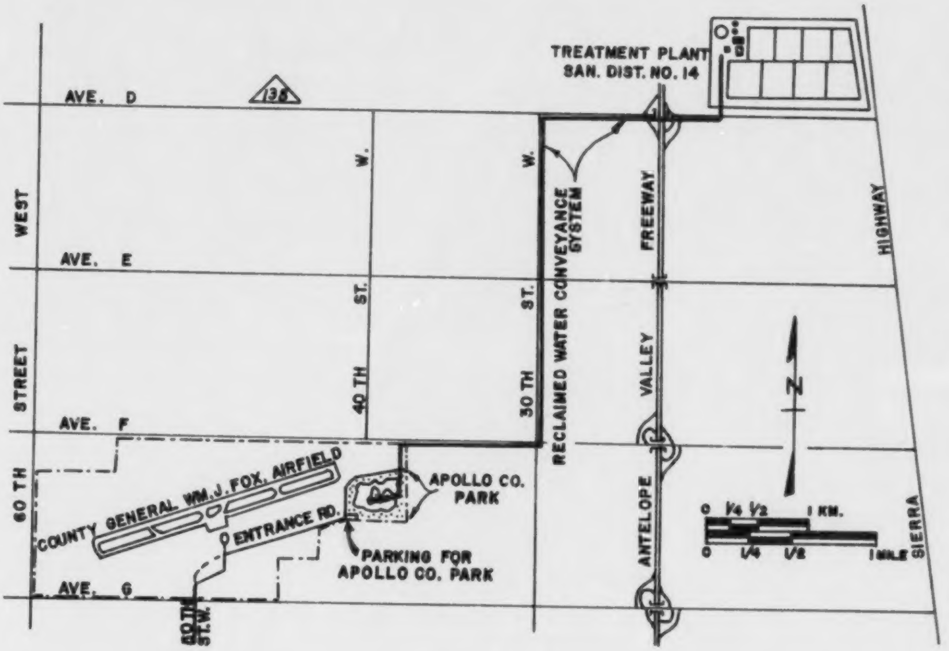


Figure 3
LOCATION MAP
ANTELOPE VALLEY WASTE WATER RECLAMATION PROJECT

sufficient for farming and industrial uses in the surrounding areas, and will be used for these purposes when additional supplies are made available.

The water quality in these lakes has been generally very good, meeting all health requirements and having a sufficiently low nutrient level to avoid eutrophication. The water appearance has been good. In terms of irrigation water quality, the water is usable. However, because of the high sodium percentage and the increases in the boron and dissolved salts due to evaporation, precautions will be necessary to maintain soil quality.

The lakes proved to be an excellent fish environment, well suited for growth and reproduction. However, due to an unforeseen natural soil condition, a mercury contamination problem resulted, causing mercury concentrations in the fish to exceed the allowable limits for human consumption. The mercury appeared to have no adverse effect on the health of the fish.

PUBLIC ACCEPTANCE

The public use of this park has exceeded expected levels, according to the preliminary data thus far assembled. Originally the public use of this park was estimated at approximately 60,000 visitor-days the first year, rising to 90,000 visitor-days in 10 years. However, preliminary traffic count data indicates a use of over 90,000 visitor-days in the second year of operation. Thus the public acceptance of this project is well established.

SECTION II
RECOMMENDATIONS

TERTIARY TREATMENT PLANT

Overall, the tertiary treatment plant performed very well and met water quality standards and supply demands. Following are recommendations to improve performance.

An increase in the alum sludge concentration would be a key improvement to the tertiary treatment process. For this reason, the feasibility of adding a process or improving the existing processes to increase this sludge concentration should be studied.

The tertiary treatment process could also be improved by altering the collection flight system of the sedimentation tank. This should be redesigned so that the return flights pass above the water surface instead of being submerged.

Additional studies on minimizing the occurences of blue green algae in the oxidation ponds might also prove worthwhile. These algae frequently hindered the treatment process because of their poor flocculation characteristics and caused a slight discoloration of the water.

APOLLO COUNTY PARK

The following recommendations should be adhered to to insure proper conditions at the aquatic park site.

The Health Department monitoring of the bacterial qualities of these lakes should continue as this will provide important public assurance of the safety of this system.

A thorough study of the mercury contamination of these lakes should also be undertaken. If a feasible solution of this problem can be found, the plan to reprovide a much desired warm water fishery can eventually be realized.

Control of the total dissolved Solids (TDS) in the Lakes' water will continue to be an important operational problem, particularly as the irrigation quality of this water is marginal. Therefore, every effort should be made to replace the water with fresh tertiary plant effluent during the cooler seasons when irrigational demands are the least. The TDS of the lakes will always tend to rise during the summer seasons due to the high evaporative losses. However, this problem could be kept within acceptable limits if enough flushing can be done in the cooler seasons.

The maintenance and improvement of soil quality in the park will also require continuing attention, particularly as these soils tend to have boron, alkali and salinity problems. Generous irrigation and other periodic appropriate soil reclamation measures should be regularly practiced.

The runoff interceptor berms surrounding the lakes should be kept in good repair to keep nutrients from the lawns and soils from entering the lakes. Future operational experience may indicate that underground drains are also needed to remove irrigation runoff from behind the berms.

SECTION III
INTRODUCTION

BACKGROUND

Need for Project

By the mid 1950's, it became very apparent to Los Angeles County authorities that even if new sources of water supply became available in the future, it was essential to conserve water resources by any means. This was especially true in the water-short high desert region of the Antelope Valley area of Los Angeles County, where the annual rainfall is very light and the water table is continually dropping as shown in Figure 4. Water supply problems in this arid region meant that all available resources had to be used for community or agricultural needs and count not be considered for much-desired regional or aquatic parks. On the other hand, projected flow estimates showed that over 11,400 cubic meters (3 million gallons) of secondary (Oxidation Ponds) treated wastewater would be wasted daily after 1967. This is shown in Figure 5. Therefore, it was concluded that the wasted water might be renovated as a supplemental water supply.

Pilot Plant Studies

In 1959, when the preliminary planning for reclamation of wastewater was started, the problems surrounding the fulfillment of such a plan were immense and included: research and development of treatment facilities that would guarantee clear, clean water; clearance for public use from health agencies; funding of the research studies and final project construction; and public acceptance of the use of reclaimed wastewater.

The initial research and testing started in July, 1964, to determine the most suitable and economical means of

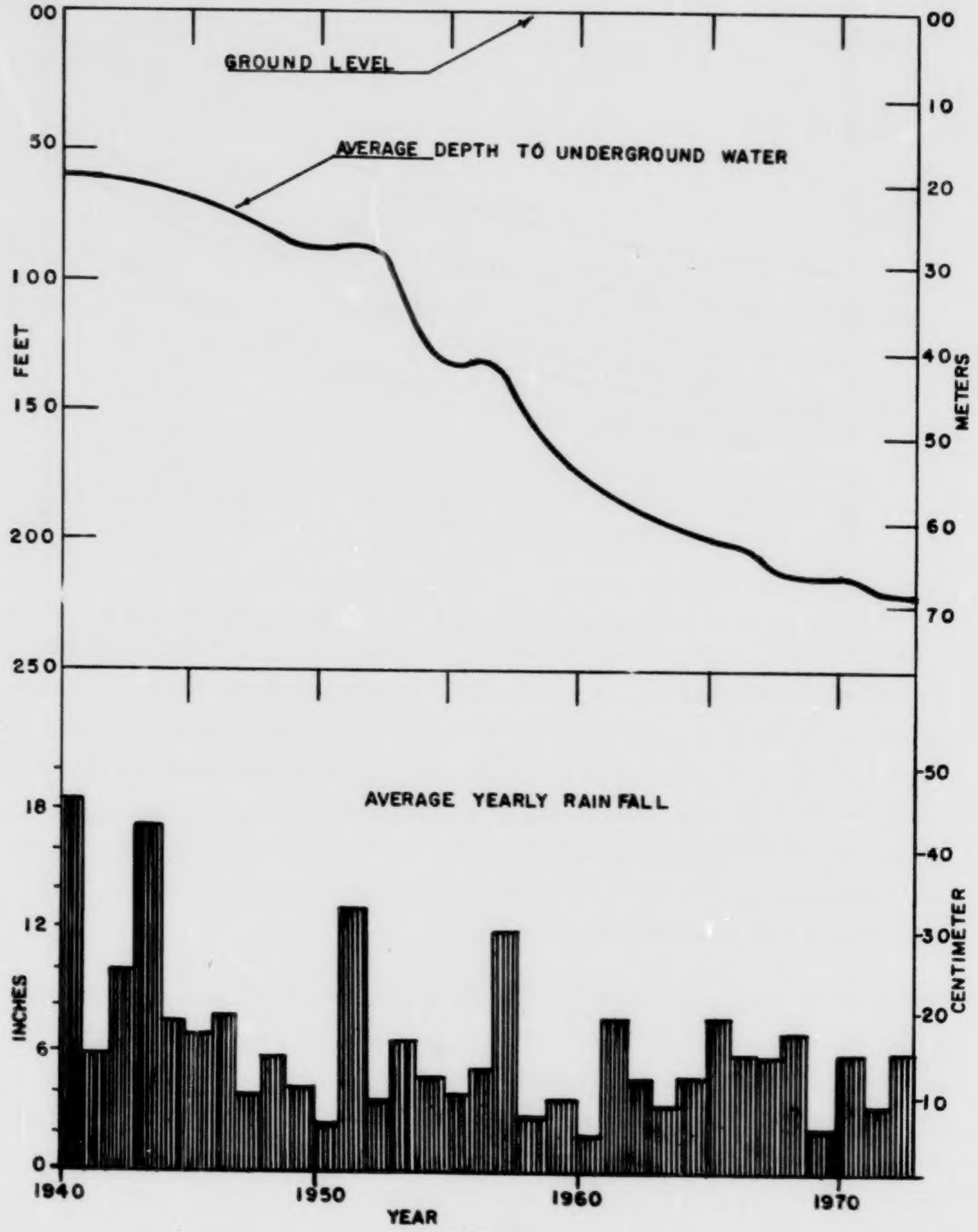


Figure 4

STATIC GROUND WATER LEVEL AND YEARLY RAINFALL
IN ANTELOPE VALLEY AREA

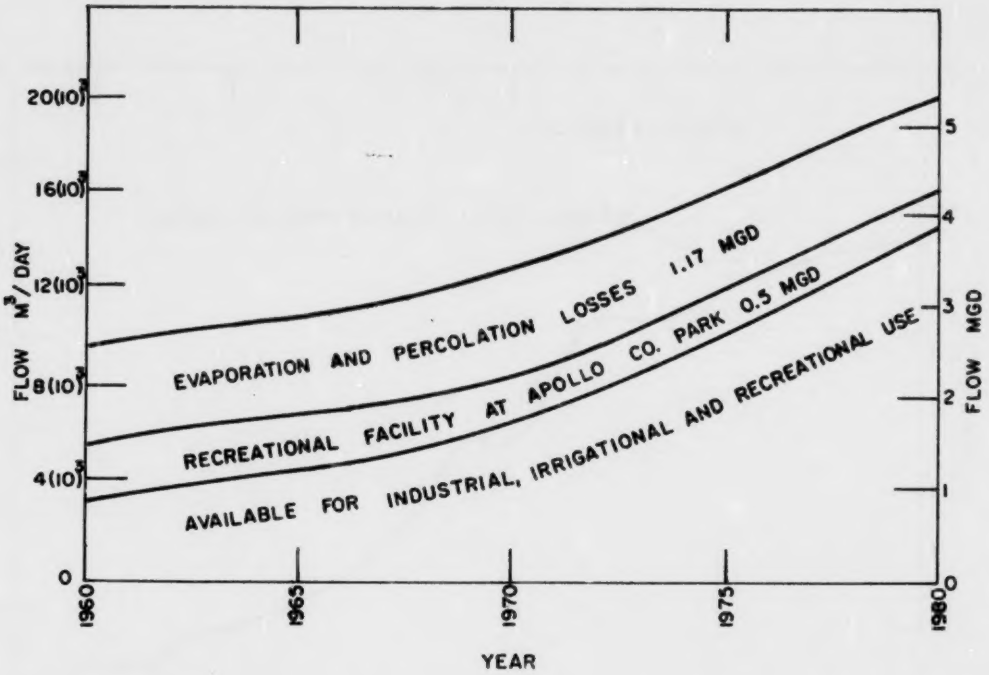


Figure 5 WASTEWATER AVAILABILITY PROJECTION FROM COUNTY SANITATION DISTRICT NO. 14 WATER RENOVATION PLANT

treating wastewater to meet the established criteria. Also, all research was done with the knowledge that if the project was to be a total success the public must ultimately accept the concept of wastewater reuse. This acceptance factor, of necessity, made clarity, color, odor and esthetics of the product water an important aspect of the research treatment processes.

Information obtained from studies by Sawyer[1] and Malhotra[2] (1964), correspondence with officials of the then Robert A. Taft Sanitary Engineering Center (1963), local health departments, Lahontan Regional Water Quality Control Board and reports available of operations of the Santee County Water District reclaimed water recreation lakes were reviewed and the minimum water quality objectives were adopted. These objectives are included in Table 1.

Table 1 PILOT PLANT AVERAGE WATER CHARACTERISTICS AND ADOPTED OBJECTIVES

Constituent	Unit	Pilot Plant Study		Adopted Objectives
		Oxidation Pond Water	Final Effluent	Water Quality
pH	pH	8.3	6.8	6.5-8.0
Turbidity	JTU	90	6	< 5
Total Alkalinity as $CaCO_3$	mg/l	260	115	<140
Susp. Solids	mg/l	75	5	< 10
Total Dissolved Solids	mg/l	600	600	<650
COD	mg/l	190	50	< 75
BOD	mg/l	38	9	< 10
Hardness as $CaCO_3$	mg/l	80	90	<110
Ammonia Nitrogen as N	mg/l	0.3	0.2	< 1.0
Organic Nitrogen as N	mg/l	7	2	< 3.0
Nitrate as N	mg/l	1.0	1.0	< 4.0
Total Nitrogen	mg/l			< 20
Total Phosphate as PO_4	mg/l	40	0.4	< 0.5
Dissolved Oxygen	mg/l	10	8	7-15
Algae	counts/ml	200,000	0	0
Coliform	MPN/100 ml	150,000	0	< 2.2
Boron	mg/l			< 1.4
Sodium Absorption Ratio				5-7
Residual Chlorine	mg/l			0.5-2.5

To determine the best tertiary treatment method to meet the wastewater reclamation objectives, the following major pilot plant processes were considered:

1. Clarifiers - High density solids contact and upflow types.
2. Dissolved Air Flotation
3. Sedimentation
4. Diatomaceous Earth Filters
5. Sand Filters and Dual Media Filters

Table 1, Pilot Plant Average Water Characteristics and Objectives, indicates the results of the pilot plant process finally adopted as compared to the water quality objectives.

In Southern California permission has been granted to use secondary treated water for irrigation although its use is limited to irrigation of trees, alfalfa, and other crops which are not consumed directly in the raw or natural state by humans; for golf courses; and, landscaping. Use of tertiary treated water for irrigation and fire protection at Apollo County Park and General William J. Fox Airfield has proved successful.

By contract with the County Sanitation Districts, approximately 11,400 m^3/day (3.0 mgd) of secondary treated water is available for tertiary treatment. Of this amount 1900 m^3/day (0.5 mgd) is allocated to Apollo County Park. This leaves 9500 m^3/day (2.5 mgd) of water, which when properly treated, could be used for irrigation, industrial or other purposes. Figure 5 indicates the wastewater availability projection from the County Sanitation District No. 14 Water Renovation Plant.

Presently reclaimed water available at Apollo County Park is 32 percent more costly than the locally pumped supplies, although it is only slightly more costly than imported water. For full water cost details, see Section VII. The local water table has historically dropped with the result being an increased cost to the consumer. See Figure 4, Static Ground Water Level and Yearly Rainfall. It was concluded that it was only a matter of time until the use of reclaimed water as a supplemental water supply would be an economic necessity in the Antelope Valley Area.

In June of 1968 the initial research programs having been successfully completed, an economical, satisfactory tertiary treatment process was adopted. This process is detailed in Section IV of this report and essentially consists of flocculation with alum, sedimentation, dual media filtration, and chlorination of secondary treated wastewater. Pilot plant test data demonstrated that bacteriological and viral requirements for tertiary treated wastewater could be met; fish had successfully survived and propagated in test ponds; algal growth and nutrient levels of water in the pilot facility were considered within the prescribed limits; review of industrial processes suggested that many manufacturing steps could use treated water with little difficulty; and a detailed soils investigation yielded a workable method for reclaiming alkaline soils, utilizing treated wastewater for leaching. The complete data and results of the pilot studies are reported in the "Final Report, Wastewater Reclamation Project for Antelope Valley Area"[3].

Full Scale Facilities

With the successful completion of the pilot research and facilities program, Los Angeles County embarked on the full scale demonstration program to show how wastewater could be reclaimed economically and used to maintain an aquatic recreational park acceptable to the public. See Figure 3, for a map of the park location.

The final research and development programs were conducted by the Los Angeles County Department of County Engineer as project director and coordinator with County and State Health Departments, County Parks and Recreation Department, County Sanitation Districts, State Department of Fish and Game, Lahontan Regional Water Quality Control Board, California Department of Water Resources as cooperating agencies. Consultants were the University of California and Engineering Science, Inc. The Environmental Protection Agency participated in the costs of the research programs and construction of the demonstration facilities through grant Nos. 17080GCI and WRD 97-01-68 commencing on August 24, 1967. On July 28, 1970, the California Department of Water Resources, under the Davis-Grunsky Act Program, participated in construction costs through fish enhancement, recreation, water and sanitary grants.

Originally there were serious doubts about the prospects for public acceptance of this project. However, continued favorable responses from the public through presentations made to social and community organizations, personal letters and news media publications showed that the public was very interested in having this project successfully carried out.

As the park neared completion in November, 1972, the local residents urged that the park be opened to the public. The initial use of the park with limited facilities (i.e., no boating, fishing, or concession facilities) was minimal in the early spring; however, as the weather became warmer, park use greatly expanded until on weekends there were problems of insufficient picnic table space. With the advent of fishing, boating and a concessionaire, the park use expanded again and extended the park use into the cold weather periods.

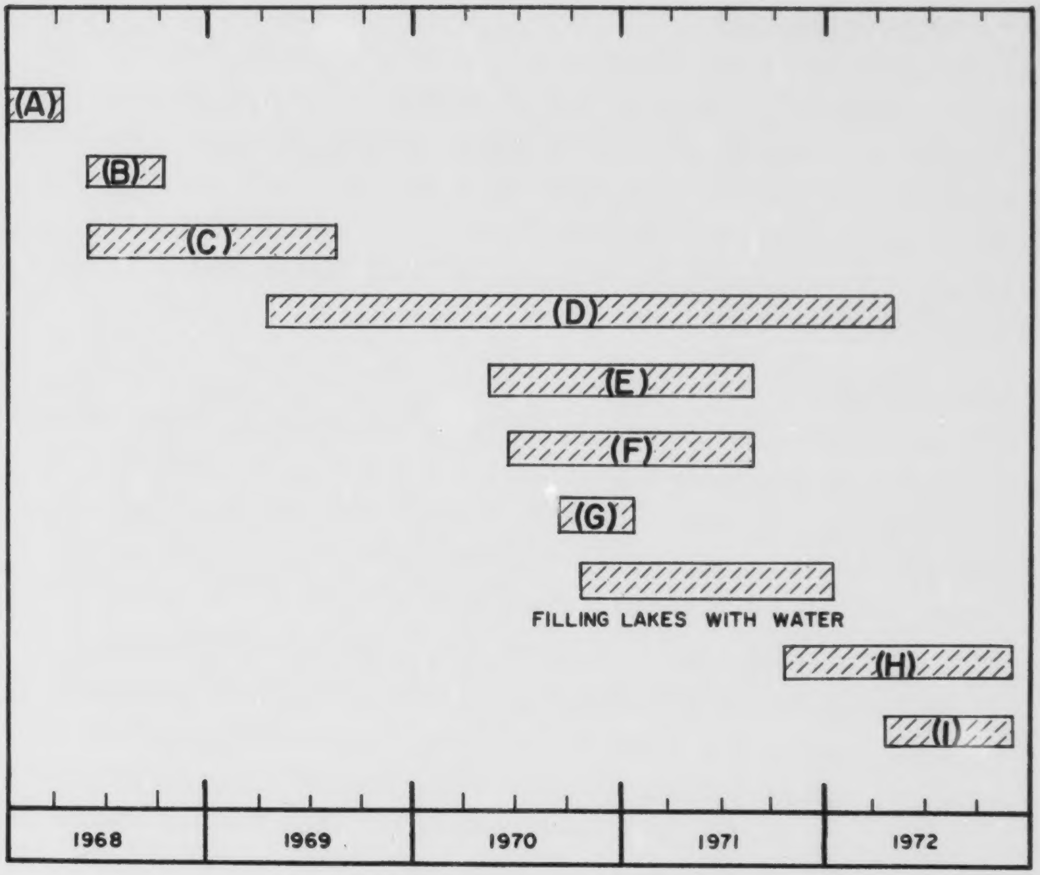
Project Completion

Construction of the demonstration project was divided into nine contracts. Each contract constituted a phase of construction leading to the ultimate construction of the park facilities. These contracts and construction periods are shown in Figure 6, but it is well to note that several phases of construction overlapped when there was no conflict of work site use.

OBJECTIVES

The primary objective of this project is to provide water-oriented recreational facilities for the water-short Antelope Valley area using reclaimed wastewater. To accomplish this objective the following secondary objectives had to be obtained first:

1. Provide an oxidation pond effluent treatment facility of sufficient size to enable engineers and scientists to conduct continuing studies under actual "full-scale" operational conditions, to hasten the development of much needed wastewater reclamation technology.
2. Demonstrate that sufficient algae and nutrient removal is realized in the treatment facility to prevent excess biological growth, to maintain aesthetic levels of clarity, and to assure an adequate aquatic habitat for fish life in recreational lakes.
3. Determine if the adopted water criteria objectives assures a safe degree of enteric pathogen and virus destruction to permit safe body contact use of reclaimed wastewater.



	Construction Contract	Construction Cost ($)
(A)	Renovated Water Conveyance System-Phase I	51,810.45
(B)	Renovated Water Conveyance System-Phase II	67,552.00
(C)	Tertiary Treatment Plant	222,450.82
(D)	Park General Development - Phase I	693,700.83
(E)	Off-Site Interceptor Sewer	118,419.57
(F)	Park General Development - Phase II	442,531.79
(G)	Lake Sealant	106,538.00
(H)	Park General Development - Phase III	290,589.96
(I)	Park General Development - Final Phase	116,653.04

Figure 6 ANTELOPE VALLEY
WASTE WATER RECLAMATION PROJECT
CONSTRUCTION CONTRACTS

4. Utilize the most satisfactory methods from current research studies to condition highly alkaline soil by leaching with treated wastewater in order to sustain plant life where only barren land now exists.
5. Demonstrate controls for any insect or noxious plant problems which occur in conjunction with such projects.
6. Demonstrate public acceptance of the use of reclaimed wastewater for establishing attractive aquatic recreational facilities, especially in water short desert areas.

SECTION IV

DESIGN AND CONSTRUCTION OF TERTIARY TREATMENT PLANT AND RENOVATED WATER CONVEYANCE SYSTEM

GENERAL INFORMATION

Upon the successful completion of the initial pilot facilities and research, design of the full scale tertiary treatment plant was commenced in 1968. This facility was designed for an average flow of 1900 m^3/day (0.5 mgd) and constructed on the site of the Los Angeles County Sanitation District No. 14 Water Renovation plant because of the closeness to the source water from the oxidation ponds. The tertiary plant was contracted for in 1968 and placed into service in June, 1969. Initially, the renovated water output was used for construction work and soil reclamation at the Apollo County Park site until filling of the lakes commenced in October, 1970.

The existing Sanitation District No. 14 plant was constructed in 1959 and serves a large portion of the developed Antelope Valley area including the communities of Lancaster and Quartz Hill. The District's plant consists of primary and secondary treatment processes as shown in the Diagramatic Layout, Figure 7.

Since the Sanitation District plant is located at the low point of the large Antelope Valley area which has no hydraulic outlet, all water either infiltrates into the ground or evaporates into the atmosphere. Even though annual rainfall averages only 15 to 20 cm/yr (6 to 8 in/yr), runoff over the eons from the nearby mountains with peak elevations over 8,000 feet, has resulted in the formation of a large flat alkaline basin known as Rosamond Dry Lake. This dry lake is located just a few kilometers east of the treatment plant site. Since this natural hard flat area is

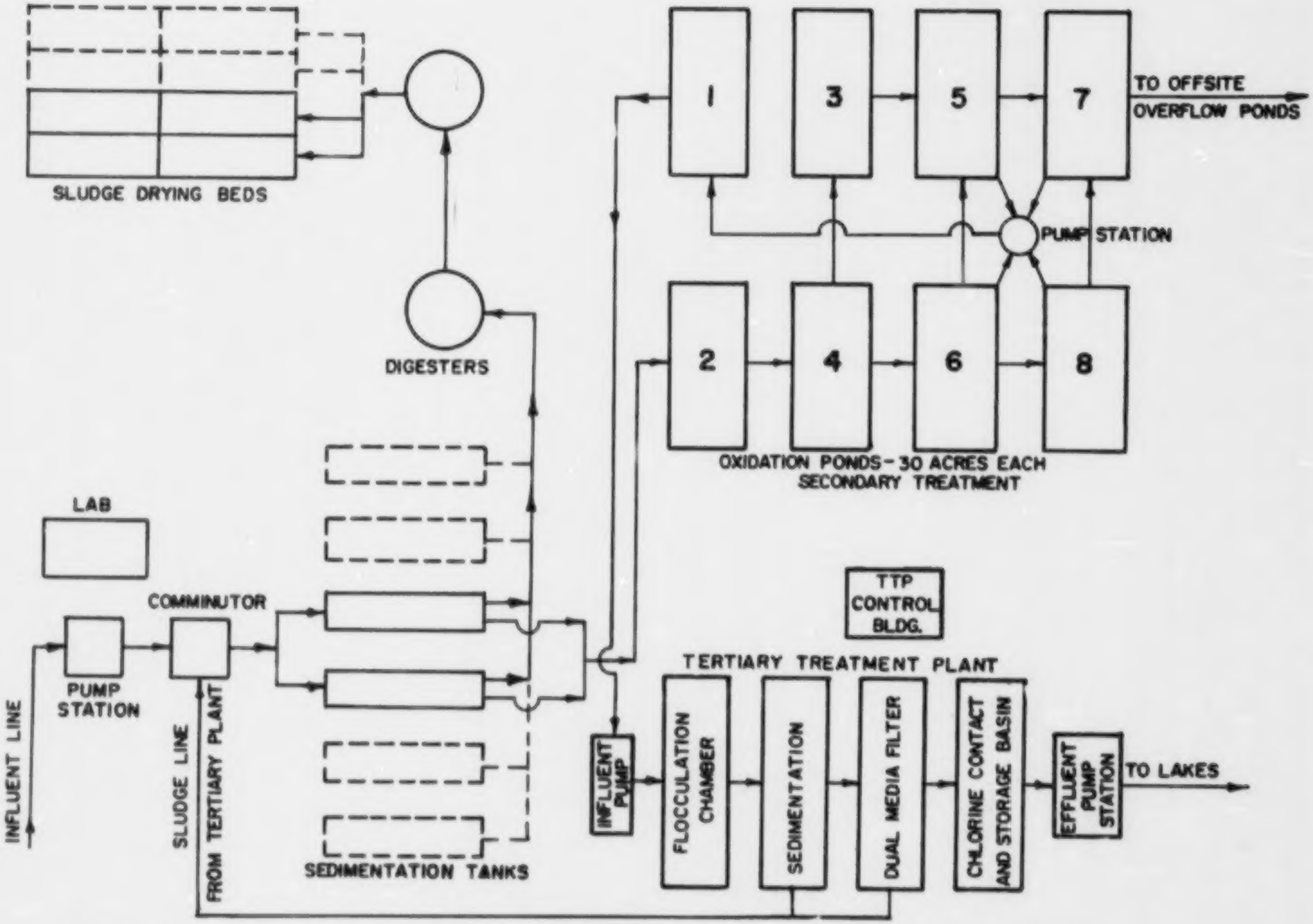


Figure 7 DIAGRAMATIC LAYOUT OF TREATMENT FACILITIES AND PROCESSES

used by the Air Force as an emergency landing field for experimental aircraft, excess wastewater from the treatment plant is presently impounded behind earthen dams to prevent its reaching and softening the surface of the dry lake. The impoundment created provides additional evaporation area and a bird refuge used by thousands of migratory birds each year.

An aerial photograph of the treatment facilities was previously shown in Figure 1, and photographs of some of the tertiary treatment plant components are shown in Figure 8.

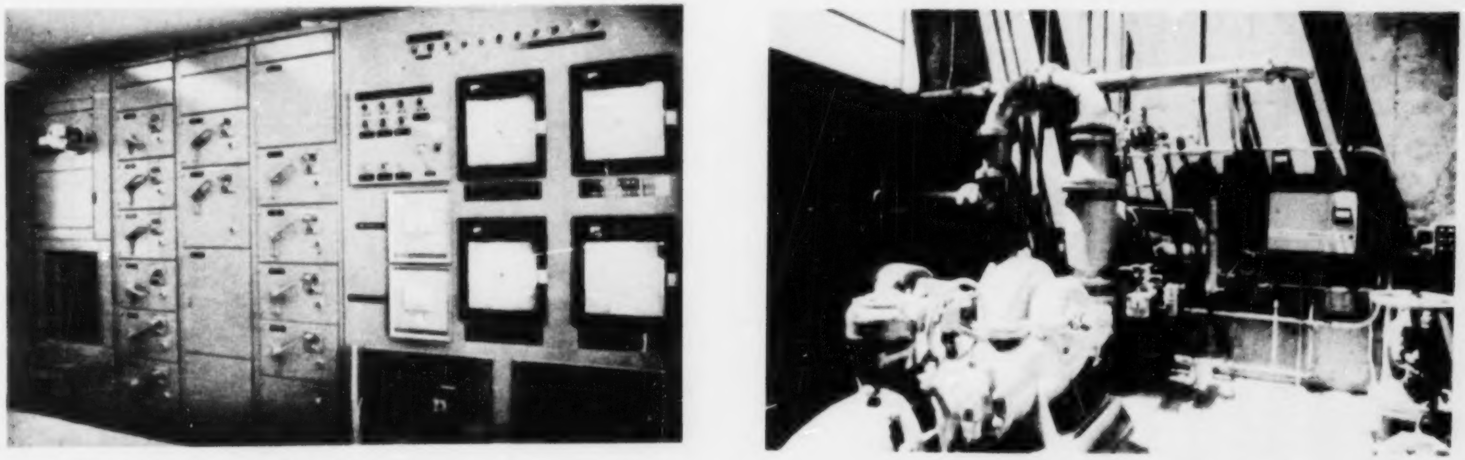
PRIMARY TREATMENT

The influent pumping plant is equipped with two 31.5 l/sec (5,000 gpm) pumps with a static lift of approximately 10.67 m (35 ft). This pumping plant is designed to expand to double its present size when it becomes necessary.

The present flow of over 11,400 m^3/day (3 mgd) passes through a comminutor and into the primary sedimentation tanks. Although two tanks have been provided in the initial stage, it is anticipated that six will be required for the ultimate design flow of 51,500 m^3/day (13.6 mgd). Each tank is 53.34 m (175 ft) long, 4.88 m (16 ft) wide and 2.29 m (7.5 ft) deep with a design overflow rate of 36.26 m/day (890 gpd/ft^2).

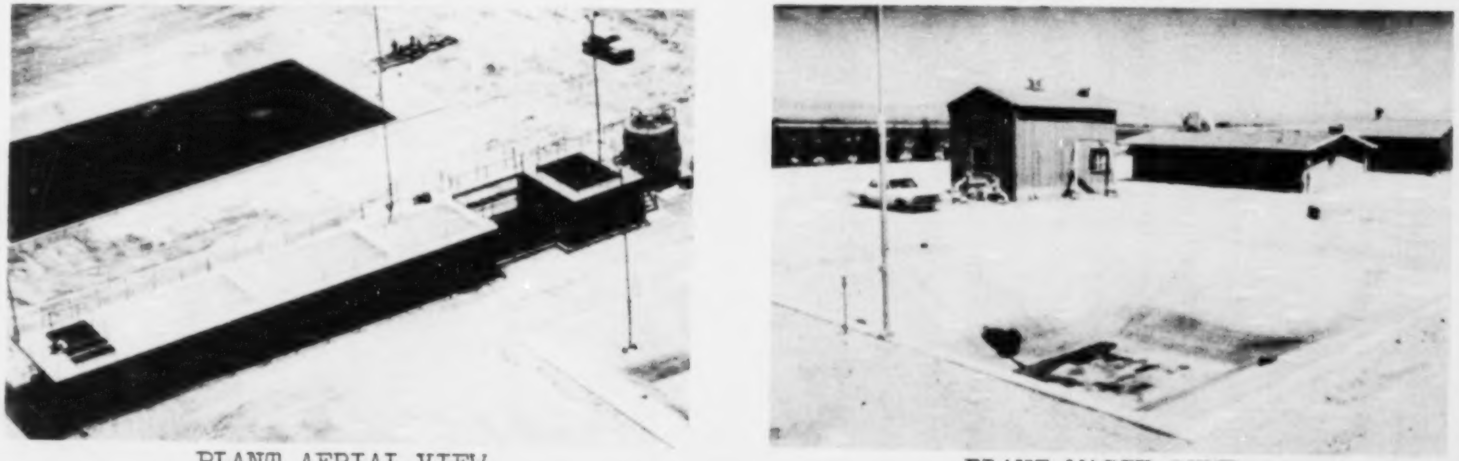
Two 19.81 m (65 ft) diameter sludge digestion tanks in series, 9.91 m (32½ ft) deep with 6.09 m (20 ft) sidewater depth provide up to 1.93 l/sec (44,100 gpd) sludge treatment within a 15-day retention period. Total sludge volume is 2310.91 m^3 (81,600 ft^3) per tank.

The treated sludge is then discharged to drying beds, with a total area of 2,790 m^2 (30,000 ft^2). After drying, the sludge is stockpiled for final disposal as a soil condi-



CONTROL PANEL

PIPE GALLERY



PLANT AERIAL VIEW

PLANT WASTE SUMP

FIGURE 8 TERTIARY TREATMENT PLANT PHOTOGRAPHS

tioner.

SECONDARY TREATMENT

Secondary treatment is provided by eight oxidation ponds with a total surface area of approximately 97 ha (240 ac). These ponds are arranged in a series-parallel arrangement and three of the ponds are equipped with diffusers to disperse the primary effluent throughout the pond. The remaining ponds further treat the primary effluent by providing substantial additional detention time. The design BOD loading is approximately 112 kg/ha/day (100 lb/ac/day) and the present acreage is considered adequate for the anticipated design flow of 51.500 m^3/day (13.6 mgd). The entire capacity was provided initially to facilitate disposal of the wastewater by evaporation because of the tight clay soil condition not allowing percolation.

Normal operation of the oxidation ponds at present as shown in Figure 7, is for primary treated effluent to be discharged into Pond No. 2. This wastewater is directed through Ponds 3, 4, and 5, and then pumped from Pond 5 to Pond 1 to complete a retention period of approximately 60 days. The pump station is so arranged that it can pump from Ponds 6, 7, and 8 also.

Organic matter is biologically decomposed by bacteria supplied with oxygen produced by free floating algae. Waste organics are metabolized by bacteria and saprobic protozoa and higher animal forms, such as rotificers and crustaceans. When the pond bottom is anaerobic, biological activity results in digestion of the settled solids. Nutrients released by bacteria are used by algae in photosynthesis. The overall process in the ponds is the sum of individual reactions of the bacteria, protozoa and algae. Excess effluent not evaporated from ponds is discharged to Ponds 6, 7, and 8 to permit additional evaporation, storage, or off-site disposal.

Pond No. 1 effluent is used for tertiary treatment. (Section VII contains a detailed description of the effluent characteristics). A 48 l/sec (760 gpm) capacity pump, operating at approximately a 10 m (33 ft) head, furnishes influent water to the tertiary treatment plant.

The degree of treatment provided by the oxidation ponds is a function of air and pond temperatures and the amount of sunlight incident on the ponds. In summer and early fall months higher water and air temperatures together with increased sunlight are sufficient to provide pond effluent with adequate treatment to reduce the effluent ammonia levels to zero. However, with cooler temperatures and reduced sunlight the effluent ammonia levels rise to unacceptable levels. For this reason only effluent with low ammonia levels is stored in pond 1 for processing by the tertiary plant.

TERTIARY TREATMENT PROCESS DESCRIPTION

As a result of the initial research and development program described in Section III, a 1900 m^3/day (0.5 mgd) capacity tertiary wastewater treatment facility was constructed at the Sanitation Districts No. 14 site at a cost of approximately $260,000. The contract was let in May, 1968, and the plant was placed in operation in June, 1969, a period of 14 months. See Section VI for a further cost breakdown.

Essentially, the tertiary treatment facility was constructed to treat water from the oxidation ponds by alum addition, flocculation, sedimentation, mixed media filtration, and chlorination to meet the objectives shown in Table 1, "Pilot Plant Average Water Characteristics and Adopted Objectives". The design and operational ranges of the tertiary treatment plant are shown in Table 2.

Table 2 DESIGN AND OPERATIONAL PARAMETERS FOR THE TERTIARY PLANT

Parameter	Unit*	Design Value	TTP Normal Range
INFLUENT FLOW	m^3/day (mgd)	2080 (.55)	(0.2-0.75) 760-2840
FLOCCULATION CHAMBER			
pH	pH Units	6.45	5.9-6.7
Alum. Dose	mg/l	300	225-450
Detention Time	min.	20	15-55
Paddle Tip Speed	cm/sec (ft/sec)	15.3-46 (.5-1.5)	15.3-24 (.5-.8)
SEDIMENTATION TANK			
Overflow Rate	m/day (gpd/ft^2)	20.5 (500)	7.5-28 (182-680)
Detention Time	Hr.	2.5	1.5-7
Flight Speed	cm/min (in/min)	91.5 (36)	48 (19)
Sludge Flow	% Plant Flow	5	12-15
Sludge Concentrate	% Solids	3	0.1-.75
FILTRATION			
Loading Rate	m/min.(gpm/ft^2)	.081 (2)	**
Final Head Loss	m (ft)	2.14 (7)	2.14 (7)
Max.Backwash Cycle	Hr.	24	**
Max.Backwash Rate	m/min.(gpm/ft^2)	.73 (18)	**
Filter Backwash Waste	m^3/day (mgd)	76 (.02)	57-76 (.015-.020)
Surface Wash	m/min @3.5 kg/cm^2 (gpm/ft^2 @50 psi)	0.81 (2)	**
Bed Expansion	%	50	**
CHLORINATION			
Influent Dose	mg/l	0	3.5-16.0
Effluent Dose	mg/l	0-15	4.5-19.0
Contact Pond Detention	Hr.	8-10	7-24
FINAL EFFLUENT			
Flow	m^3/day (mgd)	1900 (.50)	(.15-.65) 570-2460
Phosphate	mg/l	0.50	0.10-0.40
Turbidity	JTU	5	0.08-3.0
PLANT EFFICIENCY	% of infl. flow	91	77-86
ALUM COST @ $55.60/Ton	$ per 1000m^{3}eff. ($ per MG eff.)	20.40 (77)	18-29 (68-110)

* English units are shown in parentheses

** Indicates no data available

The tertiary treatment process flow diagram, layout, and hydraulic diagram are shown in figures 9,10, and 11 respectively. The basic treatment components are described in the following paragraphs.

Flocculation

Flocculation is accomplished by use of 50 percent liquid aluminum sulfate (alum). The alum is stored in a 21.20 m^3 (5,600 gal) tank constructed of fiberglass coated internally with a chemical gel for protection up to 93.33°C (200°F). The normal dosage ranges from 280 mg/l to 340 mg/l, and this dosage is measured by a diaphragm metering pump capable of pumping 1.31 l/min (20.8 gph) at 8.79 kg/cm^2 (124 psi) pressure. The pump stroke length is manually adjustable by means of a four-step multiple sheave arrangement.

The floc retention time is 20 minutes under paddle aggitation in a 2.44 m (8 ft) long, 4.88 m (16 ft) wide by 2.67 m (8-3/4 ft) deep concrete tank. Paddle agitation is performed by two reel units 1.68 m (5½ ft) in diameter and 1.68 m (5½ ft) long designed to operate at 15.24-54.72 cm/sec (0.5 to 1.5 fps) reel tip speed. The design flow for the flocculator is 23.97 l/sec (380 gpm).

To improve the mixing capability of the chamber a baffle was installed later at the sedimentation tank entrance. This baffle consists of redwood boards separated by 5.08 cm (2 in) gaps and erected vertically for a distance of 1.83 m (6 ft) to allow a 5.08-7.62 cm (2-3 in) overflow. With water at 6.1 to 6.4 pH and the paddles running at 15.24 cm/sec (0.5 fps) the resultant floc is light green in color, dense and small in size. Figure 12 Tertiary Treatment Plant Flocculation Chamber Design shows the general arrangement of the flocculation equipment.

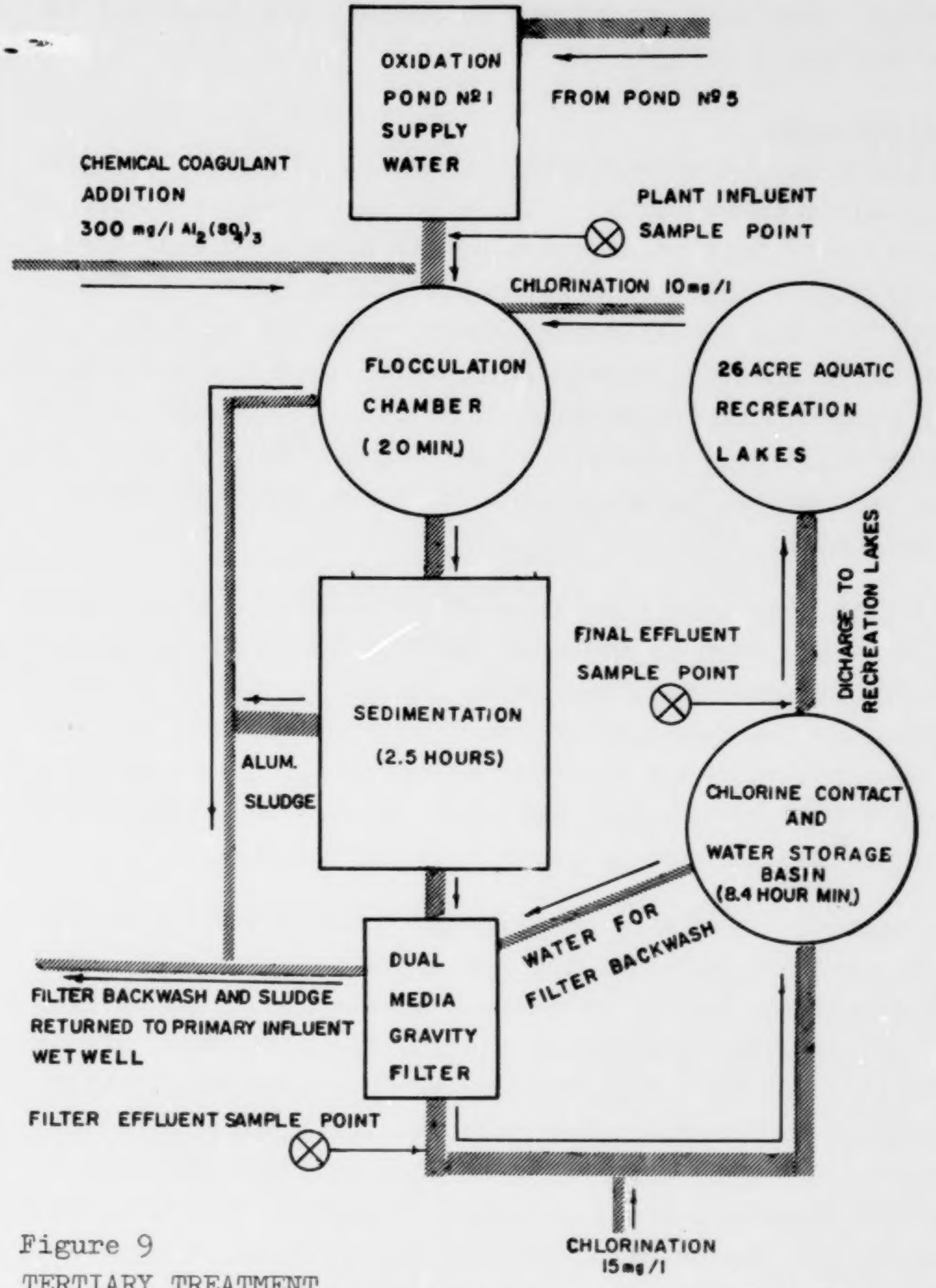

OXIDATION POND Nº 1 SUPPLY WATER
FROM POND Nº 5
CHEMICAL COAGULANT ADDITION 300 mg/l Al₂(SO₄)₃
PLANT INFLUENT SAMPLE POINT
CHLORINATION 10 mg/l
FLOCCULATION CHAMBER (20 MIN.)
26 ACRE AQUATIC RECREATION LAKES
DICHARGE TO RECREATION LAKES
FINAL EFFLUENT SAMPLE POINT
SEDIMENTATION (2.5 HOURS)
ALUM. SLUDGE
CHLORINE CONTACT AND WATER STORAGE BASIN (8.4 HOUR MIN.)
WATER FOR FILTER BACKWASH
DUAL MEDIA GRAVITY FILTER
FILTER BACKWASH AND SLUDGE RETURNED TO PRIMARY INFLUENT WET WELL
FILTER EFFLUENT SAMPLE POINT
CHLORINATION 15 mg/l

Figure 9
TERTIARY TREATMENT
PROCESS FLOW DIAGRAM - Flow = 1900 m^3/day (0.5 mgd)

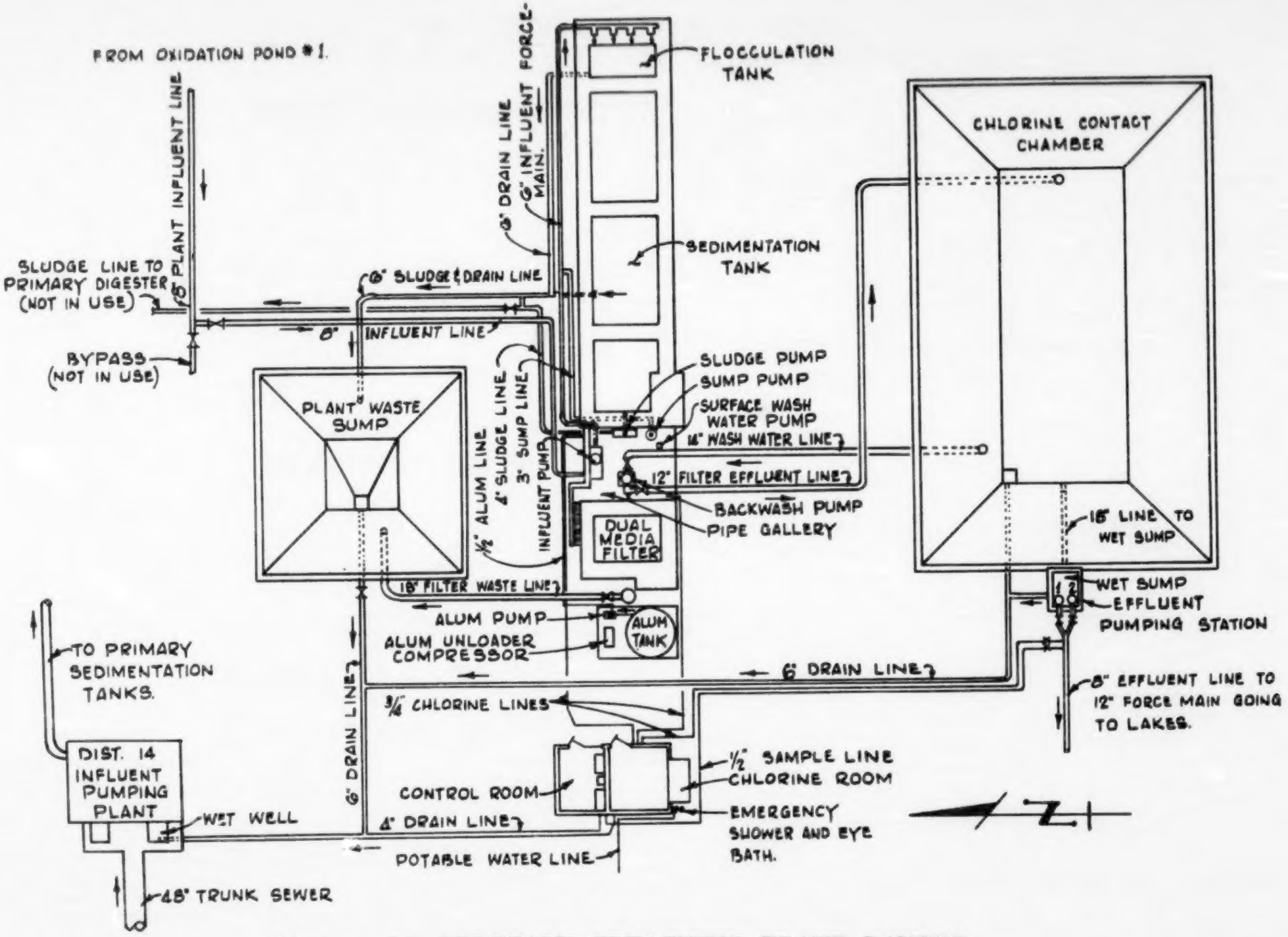
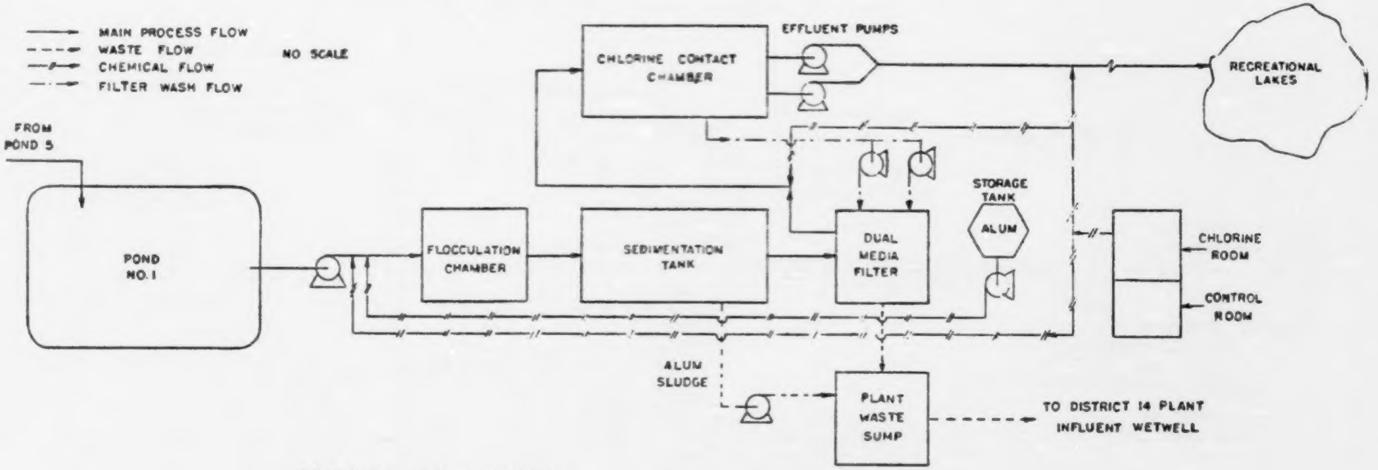
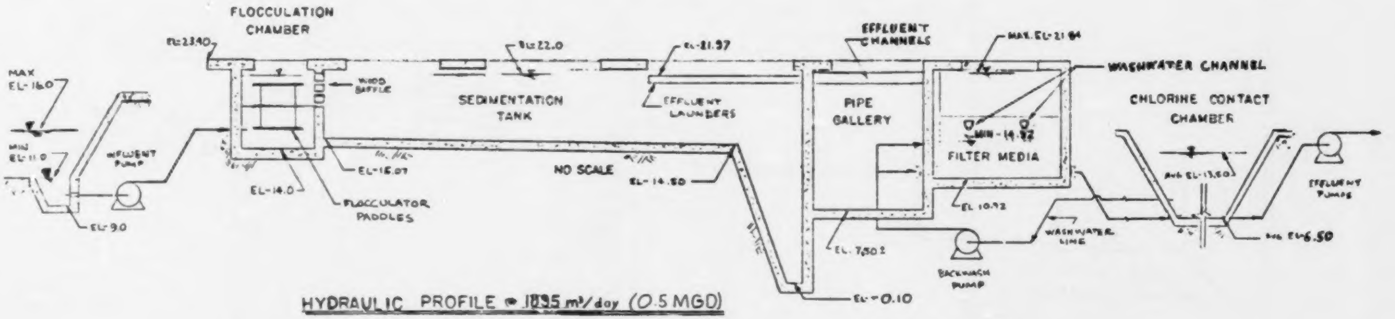


Figure 10 TERTIARY TREATMENT PLANT LAYOUT

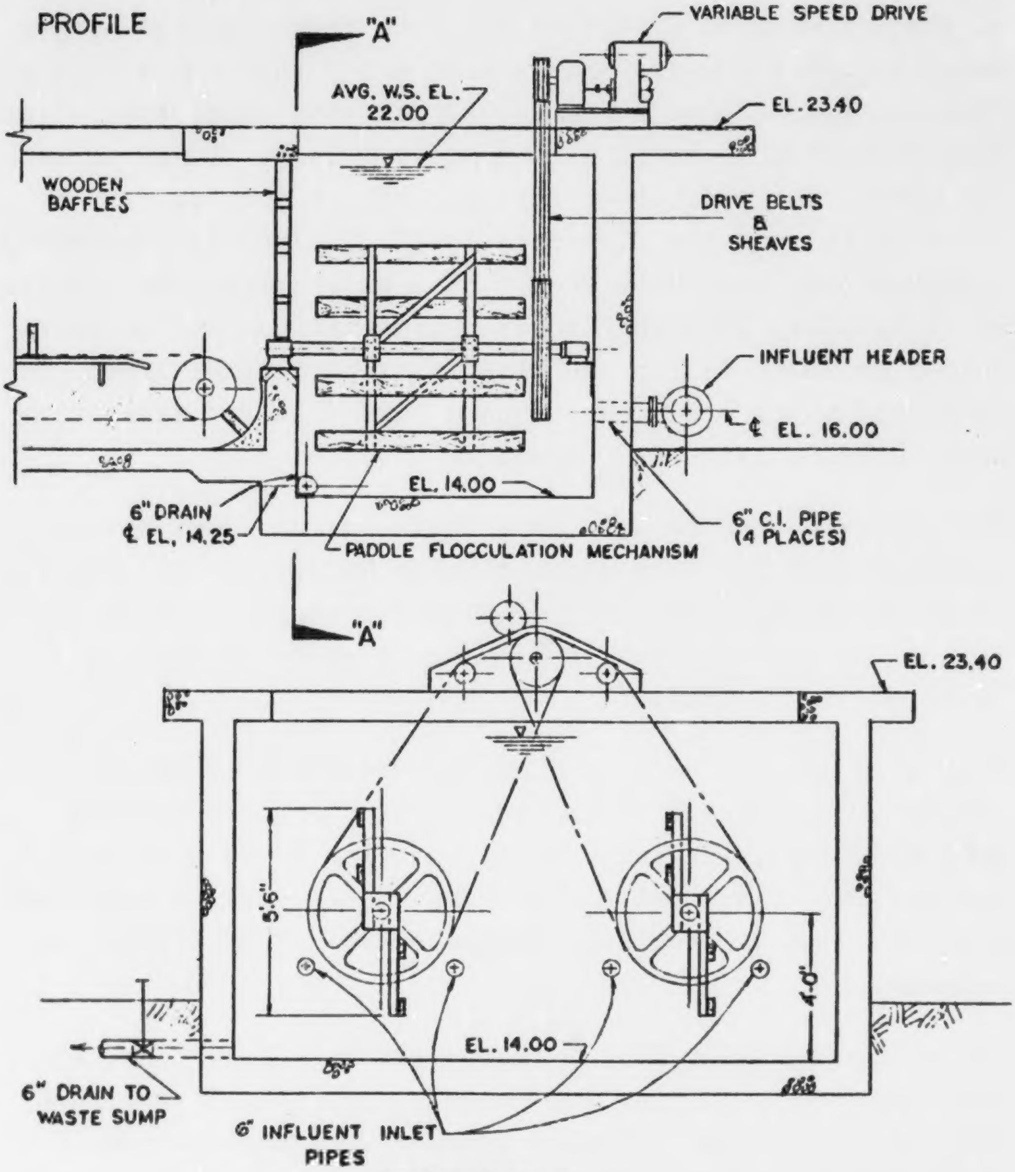


SCHEMATIC FLOW DIAGRAM



HYDRAULIC PROFILE @ 1895 m³/day (0.5 MGD)

Figure 11 TERTIARY TREATMENT PLANT HYDRAULIC PROFILE AND SCHEMATIC FLOW DIAGRAM



SECTION A-A

Figure 12 TERTIARY TREATMENT PLANT
FLOCCULATION CHAMBER DESIGN

Sedimentation

Sedimentation equipment consists of a 18.75 m (61½ ft) long and 4.88 m (16 ft) wide concrete tank, 2.29 m (7½ ft) deep at the entrance to 2.44 m (8 ft) deep at the sludge hopper end. A 1.68 m (5½ ft) wide x 4.88 m (16 ft) long x 4.22 m (14½ ft) deep sludge receiving hopper with sides that slope down to a 61 x 61 cm (2 x 2 ft) bottom and a sludge collector unit. The typical operating depth is 2.13 to 2.29 m (7 to 7½ ft) and the flow rate is 20.37 m/day (500 gpd/ft^2) although test runs have been made with satisfactory results at 28.52 m/day (700 gpd/ft^2). Sedimentation time is maintained at 2½ hours for the plant rating of 21.91 l/sec (0.5 mgd) water treatment. The design flow for sedimentation is 23.97 l/sec (380 gpm).

The sludge collector unit is a chain and sprocket driven conveyor that has 14 redwood flights 7.62 cm (3 in) thick x 20.32 cm (8 in) wide x 4.72 m (15½ ft) long placed at 3.05 m (10 ft) intervals and is designed to operate at 91.44 cm/min (3 fpm).

Presently the conveyor is running adequately at 48.26 cm/min (19 in/min). During the first year of operation some difficulty was encountered with the drive sprocket. Because this cast iron sprocket had a use life of less than six months it was replaced with one made of a plastic material.

The sludge receiver hopper is emptied by a 1.77 l/sec (28 gpm) capacity positive displacement pump operating at 280 rpm and 1.41 kg/cm^2 (20 psi) pressure. Experience has shown the need to remove the sludge at a rate greater than 1.77 l/sec (28 gpm); therefore, a by-pass valve was installed on the hopper to permit sludge to move by gravity at rates of 3.84 l/sec (60 gpm and 5.05 l/sec (80 gpm) at plant effluent capacities of 1900 m^3/day (0.5 mgd) and 2650 m^3/day (0.7 mgd).

All sludge is returned to the sedimentation units of the primary treatment plant. Although there was some concern over the possibility of this sludge disrupting the primary treatment process, no unfavorable conditions have been encountered. This experience is due to the small volume (190 m^3/day or 50,000 gpd) of returned sludge as compared to the total treatment plant flow of 65.17 l/sec (3.77 mgd). Figure 13 Tertiary Treatment Plant Sedimentation Tank Design depicts the sedimentation tank design and equipment.

Filtration

Filtration of the sedimentation process effluent is accomplished in a 3.58 m (11.75 ft) deep, 4.88 m (16 ft) wide and 4.27 m (14 ft) long concrete structure containing dual media filtering materials. The general filter arrangement consists of a 45.72 cm (18 in) gravel underlayer, a 22.86 cm (9 in) sand layer, and a 45.72 cm (18 in) anthracite top layer, all placed above a 7.62 cm (3 in) galvanized W.I. pipe underdrain system. Table 3 indicates the types of materials, their sizes, and the depth of each layer.

The underdrain gravel is composed of hard, durable rounded stones having an average specific gravity of not less than 2.5, an acid solubility of not more than 10 percent for size 0.95 cm (3/8 in) and larger or 5 percent for smaller sizes. No gravel contained more than 3 percent by weight of thin, flat, or elongated stones (the largest dimension approved being less than three times the smallest dimension) and no more than 1 percent of shale, mica, clay, sand, dirt, loam, and organic impurities. Also the gravel contained no significant amount of iron or manganese compounds.

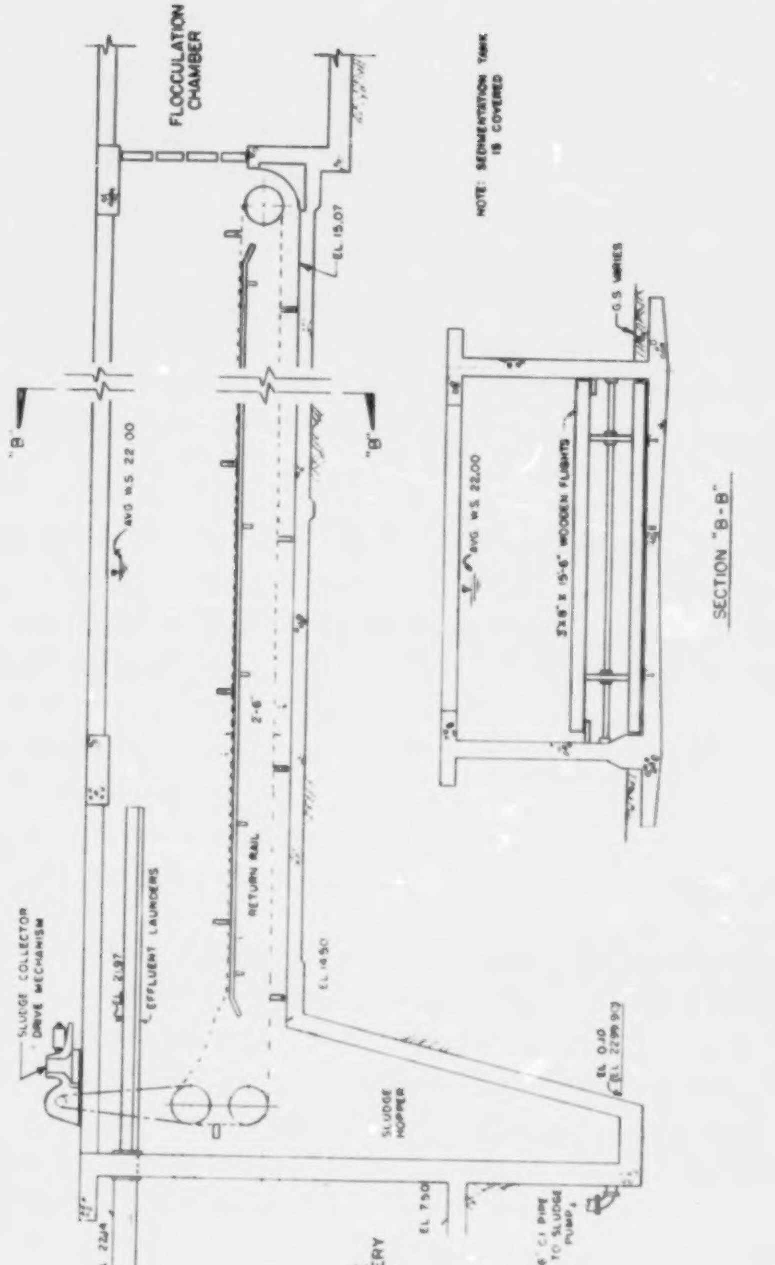


Figure 13 TERTIARY TREATMENT PLANT SEDIMENTATION TANK DESIGN

Table 3
DUAL MEDIA FILTER MATERIALS
TERTIARY TREATMENT PLANT

Material	Layer No.	Passing Screen Size	Retained Screen Size	Depth of Layer cm	Depth of Layer in
Anthracite	Top 1	**0.85mm	**0.90mm	45.72	18
Sand	2	**0.45mm	**0.55mm	22.86	9
Gravel	3	*No. 6 sieve	*No.12 sieve	7.62	3
"	4	0.64cm dia.	*No. 6 sieve	7.62	3
"	5	1.27cm dia.	0.64cm dia.	7.62	3
"	6	2.54cm dia.	1.27cm dia.	7.62	3
"	7 Bottom	5.08cm dia.	2.54cm dia.	15.24	6
			Total	114.30	45

*Screen size is square mesh except No. 6 and No. 12 sieves which conform to "Specifications for Sieves for Testing purposes" ASTM Designation E 11.

**Effective size

The 22.86 cm (9 in) sand layer is composed of hard, durable, uncoated grains containing not more than 5 percent flat particles or one percent of clay, loam, dust, and other foreign matter and complies with the "Standard for Filtering Material"[4]. All sand was also free of any significant amount of iron and manganese compounds. The loss of weight of a 2-gram sample of sand, crushed and powdered to pass through a 50-mesh screen and digested without stirring in 10 ml. of 40 percent hydrochloric acid at 18°C to 24°C (65°F to 75°F) temperature for 24 hours, was 5 percent or less.

The effective size of the sand was within the 0.45 to 0.55 millimeter range and the maximum uniformity coefficient was 1.70. Effective size is defined as that size of grain in the sample which is smaller than 90 percent by weight of all other grains in the sample. The uniformity coefficient is defined as the theoretical size of a sieve (in millimeters) that will pass 60 percent of the sample divided by the theoretical size of the sieve (in millimeters) that will pass 10 percent of the sample.

The 45.72 cm (18 in) layer of anthracite coal, composed of hard and durable grains having a specific gravity of 1.50 to 1.56, is free of iron sulfides, clay, shale, loam, dirt, and organic matter and long, thin, or scaly pieces. Anthracite hardness was maintained at 3.0 to 3.75 on the Mohs scale. The anthracite was washed, screened, and hydraulically graded coal with a uniformity coefficient of 1.80 or less and an effective size within a 0.85 to 0.90 mm range.

Operation of this dual media filter is at a rate of 81.48 $l/m^2/min.$ (2 $gal/ft^2/min$) with backwash at 733 $l/m^2/min.$ (18 $gal/ft^2/min$) for 5½ minutes and surface wash at 81.48 $l/m^2/min$ (2 $gal/ft^2/min$) at 3.52 kg/cm^2 (50 psi) when the filter water level reaches 1.98 m (78 in) above the filter bed level or 5 JTU on the turbidimeter.

The backwash pump is a 30.48 cm (12 in) suction and discharge pump capable of operating at 860 rpm and 205 l/sec (3250 gpm) at 8.08 m (26½ ft) head. The surface wash pump, a 6.35 cm (2½ in) suction and 7.62 cm (3 in) discharge pump, is rated for 22.71 l/sec (360 gpm) at a 38.71 m (127 ft) head. Figure 14, Tertiary Treatment Plant Dual Media Filter Design shows the filter and appurtenances.

Chlorination

The chlorination system is provided to prevent the spread of waterborne disease. This system consists of chlorine unloading and storage facilities, two chlorinators, and a residual analyzer located in the south portion of the

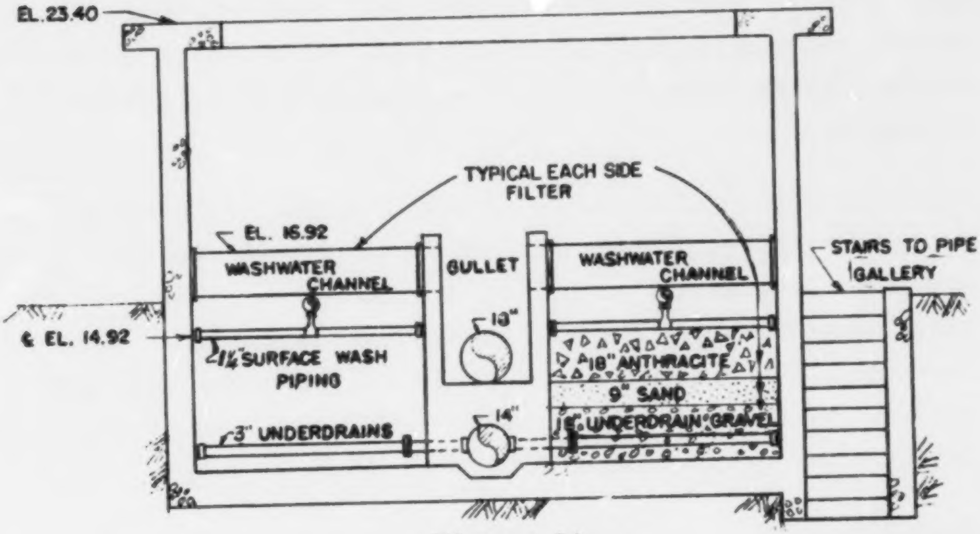


Figure 14
TERTIARY TREATMENT PLANT DUAL MEDIA FILTER DESIGN

tertiary treatment plant control building.

Chlorine storage consists of two 907 kg (1 ton) cylinders and three standby 68.04 kg (150 lb) cylinders. An automatic switchover system will switch the chlorination operation from an empty 907 kg (1 ton) cylinder to the standby cylinders so that the second full 907 kg (1 ton) cylinder can be put into service. The system is capable of supplying 45.36 kg (100 lb) of chlorine gas per day.

As the equipment is presently set up, chlorination can be performed at three locations; at the flocculation chamber, at the entrance to the chlorine contact chamber, and at the pump station directing water to the recreational lakes.

Since rapid growth of algae and bacteria in the sedimentation tank produced gases that lengthened the sedimentation process, chlorination first is performed in the floc mixing tank at the rate of 19.05 kg/day (42 lb/day or 10 ppm) to retard the growth of these organisms. At this rate, tests show a residual chlorine of 0.3 mg/l is maintained in the sedimentation tank and that the sedimentation process is improved.

A second chlorination dose of 13.62 kg/day (30 lb/day or 7 ppm) is injected into the chlorine contact chamber influent and a detention period of 8.4 hours is maintained on this contact chamber water. Residual chlorine is held between 1.0 and 2.0 mg/l. Should the chlorine residual fall below the allowable limit of 0.5 mg/l, the water can be recycled or chlorinated at the effluent pumps.

Controls

The instrumentation systems housed in the control building include the metering and control panel, the shutdown alarm panel, electrical switchboard and various field mounted meters and controls. These systems monitor or control plant operations and can be divided into three categories: (1) Indicating and recording instruments, (2) Controls on individual equipment, and (3) Shutdown alarm panel system. These three categories are summarized in tabular form in Tables 4, 5, and 6, as follows:

TABLE 4 (Indicating and Recording Instruments) lists various instruments, their function, the primary instrument location and type, and the indicator or recorder location.

TABLE 5 (Controls on Individual Equipment) shows, in tabular form the various units in the tertiary process, the type of switch used, start and stop controls, and start-up interlocks.

TABLE 6 (Shutdown Alarm Panel) summarizes the alarms and sensing instruments which control automatic plant

TABLE 4

ANTELOPE VALLEY TERTIARY TREATMENT PLANT

Indicating and Recording Instruments

Instrument	Function	Primary Instrument Location & Type	Indicator or Recorder Location
Influent Flowmeter	Indicate Flowrate	Pipe Gallery - Propeller Meter	Pipe Gallery
Effluent Flowmeter	Indicate Flowrate	Effluent Pump Station- Propeller Meter	Effluent Pump Station
Equipment Running Lights	Indicate Equipment Status	Motor Control Centers- Auxiliary Contacts in Motor Starters	Electrical Panel
Valve Position Lights	Indicate Valve Position	Pipe Gallery - Limit Switch on Pneumatic Valves	Metering & Control (M & C) Panel
pH Meters	Indicate Influent & Flocculation pH	Control Room -Beckman pH Meter	M & C Panel
pH Recorder: Red Pen	Indicate & Record Influent pH	Control Room - Beckman pH Analyzer	M & C Panel
pH Recorder: Blue Pen	Indicate & Record Flocculation pH	Control Room - Beckman pH Analyzer	M & C Panel
Turbidity Recorder: Red Pen	Indicate & Record Influent Turbidity	Pipe Gallery - Hach Surface Scatter Turbidimeter	M & C Panel

TABLE 4 (Continued)

Indicating and Recording Instruments

Instrument	Function	Primary Instrument Location & Type	Indicator or Recorder Location
Turbidity Recorder: Green Pen	Indicate & Record Filter Effluent Turbidity	Pipe Gallery - Hach Surface Scatter Turbidimeter	M & C Panel
Turbidity Recorder: Blue Pen	Indicate & Record Final Effluent Turbidity	Chlorine Room - Hach Surface Scatter Turbidimeter	M & C Panel
Filter Water Level Recorder	Indicate & Record Filter Water Level	Top of Filter - Bubbler Type Filter Level Sensor	M & C Panel
Chlorine Residual Recorder	Indicate & Record Effluent Chlorine Residual	Control Room - Wallace & Tiernan Chlorine Analyzer	M & C Panel

TABLE 5

ANTELOPE VALLEY TERTIARY TREATMENT PLANT

Controls on Individual Equipment

Unit & Switch	Start Control	Stop Control	Interlock To Start
Influent Pump H-O-A	R-1 Relay	R-1 Relay (Backwash Sequence)	a) Backwash Throttling-Valve - CLOSED b) Filter Wastewater Valve - CLOSED c) Filter Effluent Valve - OPEN
Backwash Pump H-O-A	Backwash Timer	Backwash Timer	a) Backwash Throttling-Valve - OPEN b) Filter Wastewater Valve - OPEN c) Filter Effluent Valve - CLOSED
Surface Wash Pump H-O-A	Backwash Timer	Backwash Timer	a) Backwash Throttling-Valve - OPEN b) Filter Wastewater Valve - OPEN c) Filter Effluent Valve - CLOSED
Effluent Pumps H-O-A	HWL Probe in Effluent Wet Well	LWL Probe in Effluent Wet Well	None
Sludge Pump H-O-A	R-1 Relay	R-1 Relay	Influent Pump Running
Sludge Pump H-O-A	Probe in Sump	Probe	None

TABLE 5 (Continued)

Controls on Individual Equipment

Unit & Switch	Start Control	Stop Control	Interlock To Start
Alum Diaphragm Pump; ON-OFF	R-1 Relay	R-1 Relay	Influent Pump Running
Chlorinators; H-O-A	R-1 Relay	R-1 Relay	Influent Pump Running
Instrument Air Compressor; H-O-A	Receiver Tank Pressure Switches		None
Alum Unloading Compressor; Start-Stop	No Automatic Operation		None
Sludge Collector Drive; Lock-out Stop	No Automatic Operation		None
Paddle Flocculator; Lock-out Stop	No Automatic Operation		None

TABLE 6

ANTELOPE VALLEY TERTIARY TREATMENT PLANT

Shutdown Alarm Panel

Alarm	Sensing Instrument	Significance	Possible Sources of Trouble
High Flocculation pH	High pH Contact on Circular Chart Recorder	Not enough Alum being supplies to Flocculation Chamber	Alum storage tank empty Alum Feed lines clogged Alum pump failure.
High Water Level In Filter	HWL Probe in Filter	Water Surface in filter is above Normal Operating Range	Backwash initiating water level contact on recorder not operating correctly. Filter wastewater valve malfunction.
High Water Level in Chlorine Contact Chamber	Probe in Chlorine Contact Chamber	Water Surface in Chamber is above normal operating range.	Effluent pump not on line or has failed. Slide gate to effluent pump station wet sump in closed.
Low Chlorine Residual	Low Residual Contact on Recorder	Chlorine Residual is below a pre-set level	Chlorinator or Control System Malfunction.

TABLE 6 (Continued)

Shutdown Alarm Panel

Alarm	Sensing Instrument	Significance	Possible Sources of Trouble
Low Chlorine Supply Pressure	Pressure Switch on Chlorine Gas Lines Downstream from Pressure Regulators And/or Pressure Switch on Water Line Upstream of Chlorinators.	Chlorinators not being supplies with Chlorine or water at proper pressure. Possible under-chlorination.	Main Chlorine Cylinder empty - Standby cylinders not properly connected. Water supply shut off or below minimum pressure.
High Water Level in Pipe Gallery Sump	HWL Probe	Failure of Sump Pump	Electrical or Mechanical failure.
Electrical power Failure	All alarm relays		Electrical power interruption.

NOTE: Any of the above Shutdown Alarms will shut down all plant equipment on the Automatic Process Control System.

shutdown. When an alarm is sounded, a red light on the Shutdown Alarm Panel glows, and the alarm horn sounds outside the Control Building. The alarms can be silenced by depressing the warning light switch. The red light will continue to glow, however, until the alarm condition is corrected.

RENOVATED WATER CONVEYANCE SYSTEM

Renovated water from the tertiary treatment plant, after chlorination, is being conveyed to the recreational lakes in Apollo County Park by a pump station-force main system. The pumping station was constructed as a part of the tertiary facilities in 1969. The force main system was constructed in 1968 at a total cost of more than $127,000. These systems are described in the following paragraphs.

Pumping Station

The pumping station consists of two pumps operating from a wetwell which is located at the westerly end of the chlorine contact chamber. The product water flows into the wetwell through a 45.72 cm (18") pipe and slide gate. One of the two pumps is used to draw water from the wetwell and pump through the force main system to the recreational lakes in Apollo County Park. Effluent flow is measured with a 20.32 cm (8") propellor meter capable of indicating flows between 0 and 75.70 l/sec (0-1200 gpm) and containing a six digit totalizer calibrated in 1,000 gallons.

Pump #1 is a 2-stage, vertical turbine, water lubricated pump capable of pumping 23.66 l/sec (375 gpm) at a total head of 18.29 m (60 ft). Pump #2 is a 2-stage, vertical turbine, water lubricated pump capable of pumping 47.31 l/sec (750 gpm) at a total head of 25.92 m (85 ft).

Pump #1 was installed to handle the current design flows of 1900 m^3/day (0.5 mgd) and Pump #2 to handle the future expansion flows of 3785 m^3/day (1.0 mgd). The units are controlled so that only one of the pumps can operate under the automatic start-stop circuit at any given time. The second pump can be operated in addition to the first pump, but only under manual control. The start control for the operating pump is a probe in the wetwell chamber and the stop control is the low water level probe.

Renovated Water Force Main

The force main system consists of approximately 7.24 km (23,800 ft) of 30.48 cm (12 in) diameter pipe, of which 79.25 m (260 ft) is cement-lined, somastic coated, welded steel pipe, with the remainder being class 150 asbestos-cement pipe. The alignment of the force main system is shown on Figure 3 as "Reclaimed Water Conveyance System."

With the exception of the short segment of steel pipe constructed within a bridge structure over the Antelope Valley Freeway at Avenue D, asbestos-cement pipe was specified exclusively for the force main system. This type of pipe was chosen because of its low initial cost, ease of installation and good service and function. An air and vacuum release valve is located approximately midway in the force main to protect the main from collapsing or being blocked by entrapped air.

The force main system was constructed in accordance with the Standard Specifications for Public Works Construction[5]. The line was placed from 1.22 to 3.05 m (4 to 10 ft) deep, at relatively flat grades. All pipe was subjected to a four-hour, 1406 kg/cm^2 (200 psi) pressure test and water leakage was limited to 16.5 l/hr/100 couplings (4.24 gal/hr/100 couplings).

To identify this force main as a renovated water pipeline, a 5.08 cm (2 in) wide strip of yellow chlorinated rubber paint was applied on top.

SECTION V

DESIGN AND CONSTRUCTION OF PARK SITE

INTRODUCTION

As a result of an 18-month pilot plant study conducted at Lancaster during 1964-66, it was determined that the wastewater renovation process developed was economically feasible and the tertiary treated product water was pathogenically safe, esthetically pleasing, and suitable for fish life and recreational use. With additional financial assistance from the State of California, under the Davis-Grunsky Act, the Apollo County Park, an aquatic recreational oriented development, was planned and constructed.

The park site, consisting of 22.7 ha (56 acres) of land devoid of all vegetation except a few straggly sagebrush and weeds, is located on County owned property at the east end of General William J. Fox Airport which is approximately four miles northwest of Lancaster. This site was selected for its ideal location that is readily available from State and local highways, including the Antelope Valley Freeway, and the adjacent airport.

The focal point of the aquatic park is a chain of three lakes,shown in Figure 15, filled with approximately 303,000 m^3 (80 million gallons) of polished renovated wastewater for sport fishing and boating. Other facilities provided in the park include an amphitheater, picnic shelters, overnight camping sites, playgrounds, comfort stations, concession and service buildings, a boat dock, fishing pier, fish cleaning building, Tom Sawyer raft, and an Apollo 11 capsule building. Commemorative Apollo 11 astronaut plaques are described in Figure 16.

The development and construction of the park was staged in

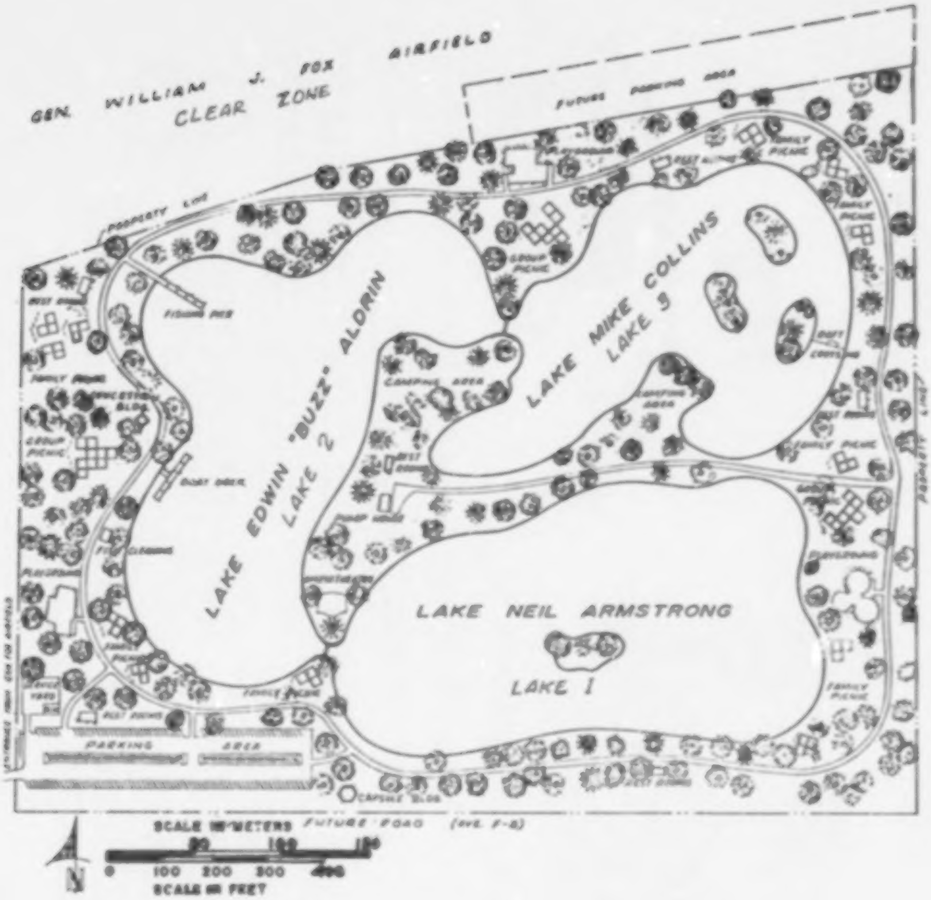
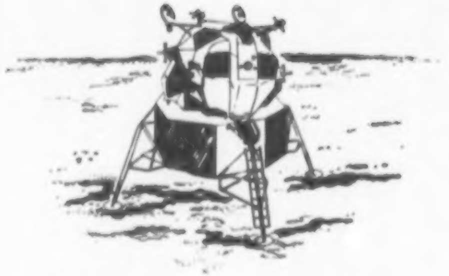


Figure 15 DEVELOPMENT PLAN, APOLLO COUNTY PARK

four phases. Phase I consisted of general grading and forming of the lakes, and construction of an irrigation system. Phase II included the construction of access and on-site roads, parking lots, and fresh water and sanitary facilities. Phase III was comprised of the installation of family and group picnic areas with shelters, an amphitheater, fish cleaning shed, fishing pier, children's play areas, and soil reclamation and landscaping work. Phase IV encompassed the construction of a concession building and an Apollo 11 Capsule Building. These facilities are further discussed in detail on the following pages.

LAKE NO. 2



LAKE EDWIN "BUZZ" ALDRIN

Dedicated to Edwin E. Aldrin, Jr., Colonel, United States Air Force, National Aeronautics and Space Administration Astronaut.

Colonel Aldrin was lunar module pilot for Apollo XI, July 16-24, 1969—the first manned lunar landing mission—and as such, performed a remarkable feat in landing the vehicle, Eagle, by flying manually to the area known as Tranquility Base.

He followed Neil Armstrong onto the surface of the moon on July 20, 1969, and completed a two-hour and fifteen-minute lunar walk, assisting in the collection of lunar surface samples, and making evaluations of the moon's terrain.

With great skill, Edwin "Buzz" Aldrin maneuvered man's first ascent from the lunar surface for a successful rendezvous with command module pilot Michael Collins who had remained in lunar orbit in the command module, and the three astronauts made a triumphant return flight to earth.

LAKE NO. 1

LAKE NEIL ARMSTRONG

Dedicated to Neil A. Armstrong, National Aeronautics and Space Administration Astronaut.

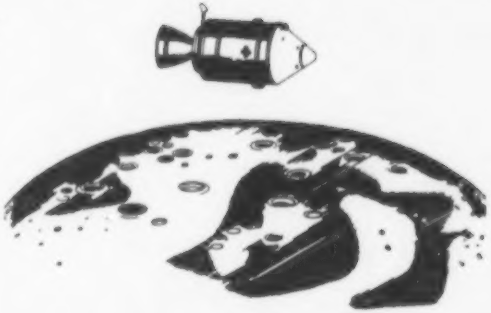
Neil Armstrong was spacecraft commander for Apollo XI, July 16-24, 1969—the first manned lunar landing mission—and became the first man to walk on the moon.

The whole world watched and thrilled to his words as he stepped onto the lunar surface from the ladder of the lunar module, Eagle, and said, "That's one small step for a man, one giant step for mankind."

On July 20, 1969, Neil Armstrong completed a two-hour and forty-minute exploration of the area of the moon near the lunar landing base, Tranquility, and provided an extensive evaluation of the terrain by personal observation and photographs which will be of vital importance to future generations.

After exploration of that desolate, windless world with lunar module pilot Edwin E. Aldrin, Jr., a rendezvous with the command module, Columbia, piloted by Michael Collins, was successfully achieved, and the three astronauts returned to earth to receive accolades for their skill and bravery from people and governments throughout the world.

LAKE NO. 3



LAKE MICHAEL COLLINS

Dedicated to Michael Collins, Colonel, United States Air Force, National Aeronautics and Space Administration Astronaut.

Colonel Michael Collins served as command module pilot on the Apollo XI mission, July 16-24, 1969, the first manned lunar landing mission.

Michael Collins maintained a lonely vigil in lunar orbit aboard the command module, Columbia, while Neil Armstrong and Edwin Aldrin, Jr., descended to the lunar surface in their lunar module, Eagle.

Exhibiting cool deliberation and an exemplary command of the most intricate manual and automated techniques, Michael Collins skillfully performed the re-docking maneuvers necessary for him to be reunited with his companions in space.

Together once again, the three courageous astronauts returned to earth where they were honored by king and commoner alike for the successful completion of one of the most perilous journeys of all time.

Figure 16 LAKE NAME PLAQUES

SOIL RECLAMATION

The native soils in the park site contain unusually high concentrations of elemental boron and salts with underlying layers of impermeable clay. These conditions render the land incapable of supporting plant life. Consequently, a detailed soil investigation was conducted resulting in a workable method for reclaiming alkaline soils.

The adopted soil reclamation procedure consisted primarily of the following:

1. Install a drainage system for leaching basins.
2. Leach the soil extensively with renovated waste water.
3. Amend the soil with gypsum or sulfuric acid.

Location

Although the park site, other than the lake areas, to be landscaped consists of 12.14 ha (30 ac), only 3.24 ha (8 ac) located at the northwest park boundary was used for soil reclamation. This area was chosen since it abutted a natural drainage course and was outside of the lake excavation and lawn areas, yet easily accessible for soil spreading purposes.

Structural Description

The leach field essentially was constructed as a rubble drain over which had been placed soil that could then be leached of deleterious salts by basin flooding.

Initially 10.16 cm (4 in) diameter perforated vitrified clay pipes were installed in 15.24 x 15.24 cm (6" x 6") gravel filled trenches 15.24 cm (6") below existing grade surface and outletting to the natural drainage with a 0.25% slope at a 6.10 m (20 ft) center to center row spacing. (See Figure 17). Over these drains was placed one foot of soil.

Then 20.59 kg/m^3 (25 tons/ac.ft) of gypsum, a soil amending agent, was disc harrowed 18.24 cm (6 in) deep into this soil from perpendicular directions so as to obtain uniformity of mixing. This operation was performed four times, then levees 91.44 cm (3 ft) high were constructed on the outer edges to hold in the leach water. Additional levees approximately 36.68 to 91.38 m (120' to 300') long were placed 6.10 m (20 ft) apart to localize this water in 6.10 m (20ft) wide basins.

Leach water was applied at a depth of 45.72 cm (18 in) each leaching cycle. Approximately 8600 m^3 (7 ac.ft) of water was used for each 1230 m^3 (1 ac.ft) of soil.

However, this soil reclamation process did not proceed as quickly as planned, and, in order not to delay the overall construction program, the soil was spread over the park site at a depth of 60.96 cm (2 ft) before reclamation was complete.

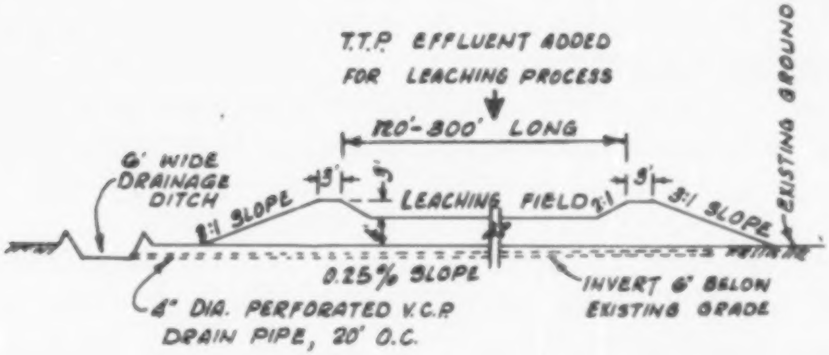


Figure 17 SOIL RECLAMATION PROCESS AT PARK SITE

The contractor for a succeeding phase of the park construction project then attempted to complete the reclamation by discing gypsum into the top 15.24 cm (6 in) of soil over the park site at a proportion of 20.59 kg/m^3 (25 tons/ac.ft). Irrigation was then reapplied to leach the soil in place. This attempt was only partially successful because, without a grass cover, too much of the applied water ran off and would not enter the soil for effective leaching. Also, much of the irrigation had to be curtailed so as not to interfere with the construction of other park facilities.

Leaching and Chemical Data

The criteria for classification of saline and alkali soils is based on the determination of electrical conductivity and percentage of exchangeable sodium in the soil. In addition to excessive salts of sodium and/or absorbed sodium ions, alkali soils may, as in Apollo County Park, contain high concentrations of boron.

Boron is essential for plant growth at very low concentrations, but when the concentration of boron in a soil saturate extract sample exceeds one milligram per liter, some plants fail to grow.

The criteria for acceptable soil for use at Apollo County Park was as shown in Table 7.

Table 7 AGRICULTURAL SUITABILITY
Maximum Desirable Values

Salinity*	2 millimhos/cm @ 25°C
Alkalinity	15% E.S.P. (Exchangeable Sodium Percentage)
Boron	0.7 mg/l

*Upon use of gypsum as a soil amendment, the salinity extract test value was increased to 4 millimhos/cm @ 25°C.

These values were determined from studies made by Engineering-Science, Inc. In 1966 this firm was contracted by the County of Los Angeles to study soil conditions at the proposed park site under a Federal Water Pollution Control Administration Grant No. WPD-50-02-65. The results of the report are detailed in Final Report, Wastewater Reclamation Project for Antelope Valley[3]. Recommendations made in this study were utilized in the soil reclamation processes used at Apollo County Park. Soil test locations and existing conditions are illustrated in Figure 18 and test results are tabulated on Table 8.

LAKES

The main feature of Apollo County Park is the aquatic recreation facilities that center about three lakes. The renovated water stored in the lakes not only provides the community's recreation needs and the park's irrigation and fire fighting source, but also will serve as a new source of water for new industries and the gradual reclamation of the nearby undeveloped marginal land.

General Design Features

The three lakes are named Buzz Aldrin, Mike Collins, and Neil Armstrong, in honor of the Apollo 11 astronauts who were members of the first lunar landing team. Covering approximately 10.52 ha (26 acres), the lakes contain 307,000 m^3 (81 million gallons) of renovated water and are 4.57 m (15 ft) deep at the lowest point. Lake Armstrong has one island approximately 21 m wide x 49 m long (70' x 160'), located centrally about 43 m (140') off the south lake shore. Lake Collins has three islands approximately 18.29 m wide x 43.89 m long (60' x 144') located 12.19 m and 18.29 m (40' and 60') from the shoreline. All islands are irrigated with reclaimed water and are landscaped with ground cover, shrubs and trees.

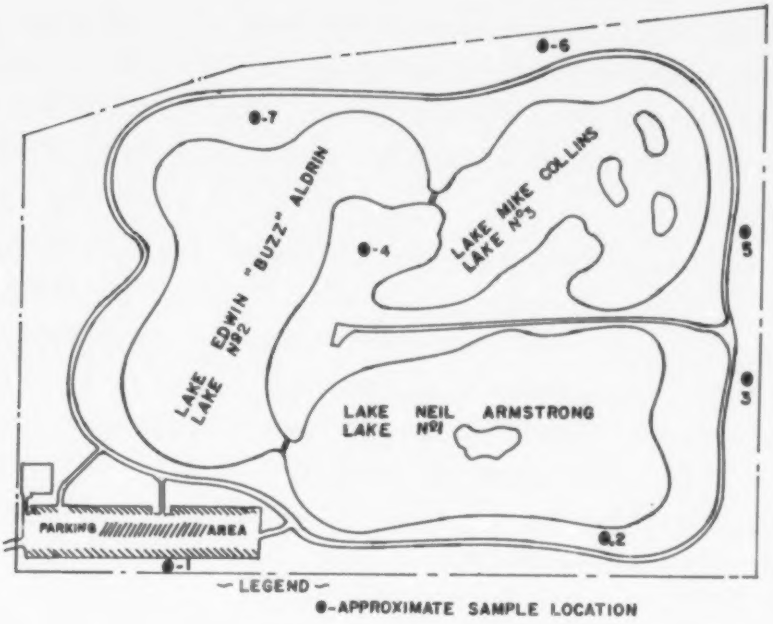


Figure 18 SOIL TEST LOCATIONS AT PARKSITE

Table 8 AGRICULTURAL SUITABILITY TEST RESULTS FOR SOIL

Location	Salinity millimho/cm	Boron ppm	Alkalinity % ESP (1)
1	3.0-4.5	4.5-6.05	7-13
2	4.0-6.5	12.7-22.20	15-18
3	5.1-7.0	7.20-11.30	17-23
4	3.6-4.5	2.40-2.54	8
5	4.7-6.5	6.00-8.05	12-15
6	6.5-6.1	8.70-19.80	15-23
7 (2)	5.7-7.5	4.59-10.60	4-5
Desirable	2.0 (3)	0.70	15

(1) Exchangeable Sodium Percentage

(2) All test samples taken at 15.24 cm (6-inch) depth except the 30.48 cm (12-inch) depth at location No. 7.

(3) Upon use of Gypsum as a soil amendment, the salinity extract value was increased to 4.0 millimhos/cm.

Access to the islands is by boat but the southern island in Lake Collins is also accessible by raft. To enhance the use of the lakes as a fish hatchery, several fish shelter areas were constructed in the three lakes. These fish shelters are described in detail in this Section under "Fishing".

One of the design features for the lakes is that the water within the lakes can be circulated. This is normally accomplished in the pump house when water is withdrawn from the lakes for irrigation purposes or by use of a circulation pump. Circulation of lake water can also be accomplished by the opening of an overflow culvert between Lakes Armstrong and Collins, by the opening of drain structure valves located at each lake, or by lake water passing through open stop log structures.

Pump House and Controls

The pump house containing the main water control works is in a central location between the three lake areas. These control works, as shown in Figure 19, regulate flows to and pump water from each of the lakes. The main control works including pumps, electrical, and gauging equipment, and a laboratory for on-site testing of water samples are housed in the structure. A standby fire pump, a sprinkler system pump, and a recirculation pump are provided.

All pumps are vertical turbine units with 1760 rpm, 60 cycle, 3 Ph, 460 V. everseal encapsulated electric motors. The recirculation pump is single stage with a 20.32 cm (8") discharge, 20.32 cm (8") column, and is driven by a 10 HP motor. The sprinkler pump is 6-stage with 20.32 cm (8") discharge, 20.32 cm (8") column and is driven by a 60 HP motor. The fire pump is 2-stage with 25.40 cm (10") discharge, 25.4 cm (10") column, and is driven by a 150 HP motor. The design features are tabulated in Table 9.

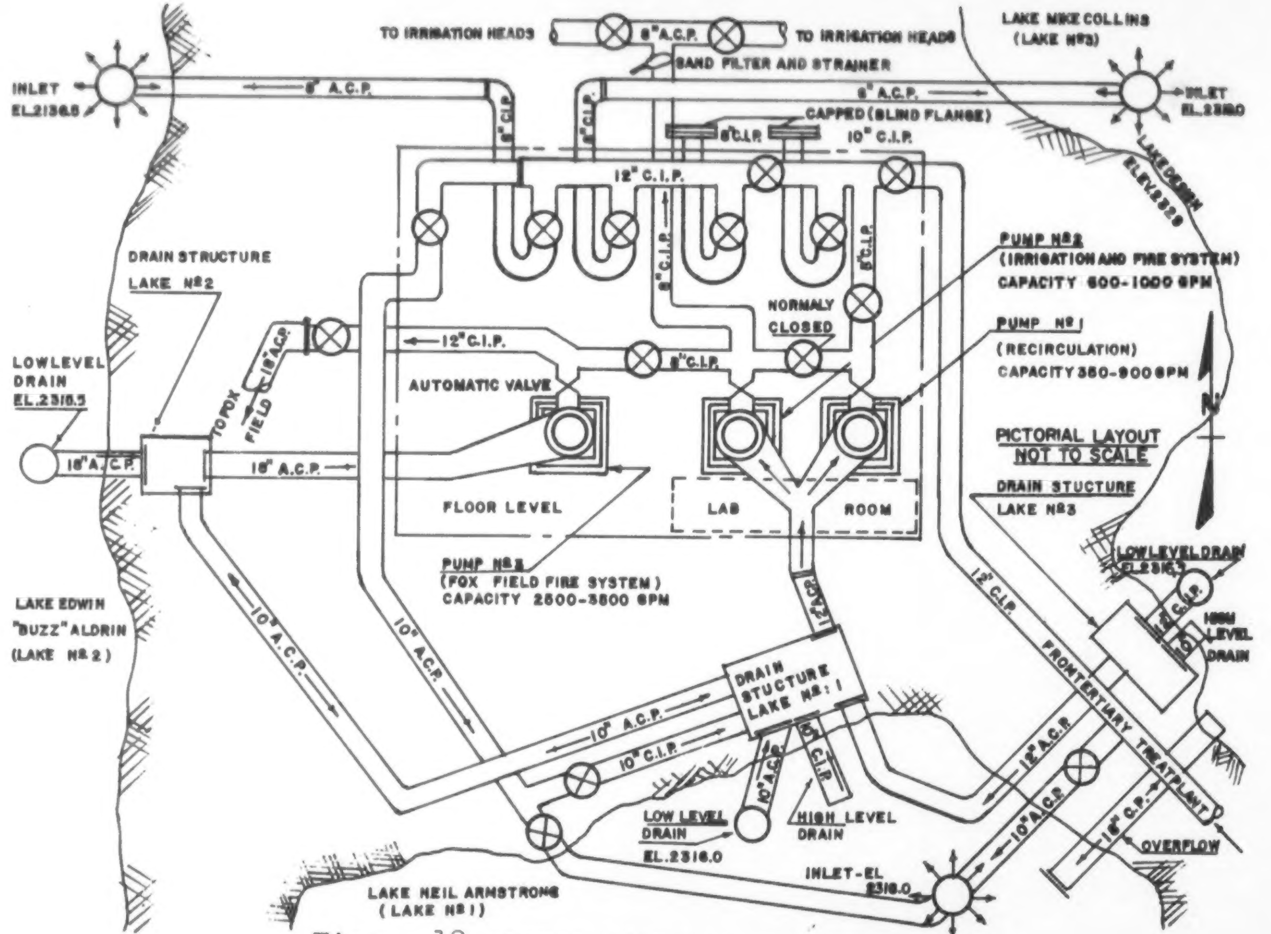


Figure 19 APOLLO COUNTY PARK DIAGRAMATIC LAYOUT OF PUMP AND VALVE CONTROLS

Table 9 PUMP FLOW CHARACTERISTICS
APOLLO COUNTY PARK CONTROL FACILITY

RECIRCULATION PUMP

Capacity		Head			
L/sec	gpm	m.	ft.	Minimum Bowl Eff.(%)	Maximum B.H.P.
22.1	350	16.8	55	62	7.7
45.7	725	13.7	45	80	10.2
56.8	900	9.1	30	76	9.0

SPRINKLER PUMP

Capacity		Head			
L/sec	gpm	m.	ft.	Minimum Bowl Eff.(%)	Maximum B.H.P.
37.8	600	85.3	280	81	53
50.5	800	71.6	235	80	60
63.1	1000	50.3	165	72	58

FIRE PUMP

Capacity		Head			
L/sec	gpm	m.	ft.	Minimum Bowl Eff.(%)	Maximum B.H.P.
157.7	2500	57.3	188	76	158
189.2	3000	52.7	173	80	165
220.8	3500	43.9	144	81	165

In an emergency, each pump can be used for another purpose by a manifold system located within the pump house; also as shown in Figure 19, water is available from any lake by the use of interconnected drain structure.

Pump No. 1 is manually used when circulation in the lakes is necessary. This recirculation pump draws water directly from Lake No. 1 drain structure which is then discharged to Lakes No. 2 and 3 drain structures as shown on Figure 19. By the opening or closing of the proper slide valves in the drain structures, water may be regulated to any lake.

Pump No. 2 supplies irrigation and fire protection to the immediate park site. This pump draws water in the same manner as Pump No. 1 and conveys it through 20.3 cm (8") asbestos cement pipes to the park fire hydrants and irrigation system. This pump is pressure controlled and is further described under "Irrigation".

Pump No. 3 is primarily a fire protection system pump for the General Wm. J. Fox Airfield. Water from this pump flows directly to the airfield, but a by-pass valve also permits the use of this pump as an auxiliary pump for park irrigation. Pump influent water is normally drawn from Lake No. 2 drain structure. However, as shown on Figure 19, by the opening or closing of the proper slide valves in the drain structures water may be drawn from any lake.

All pumps are controlled from a panel board located inside the pump control building. The panel board contains an integrated hydraulic and electric pump control system. Pumps No. 2 and 3 are controlled by manual switches that select either automatic or hand operation cycles for pump use. Automatic cycling permits starting and stopping of pumps on pre-set pressures. Both automatic cycling systems are transferable, since a manual plug system has been installed for this purpose. Pump No. 1 has only a manual control switch. Under automatic control, Pump No. 2 will start when pressure in the pipe system drops to 5.98 kg/cm^2 (85 psi) and stop with a rise in pressure to 8.44 kg/cm^2 (120 psi).

During fire hydrant use a drop in system pressure to 3.87 kg/cm^2 (55 psi) will cause the controls to shut down the irrigation system and it will remain down until the pressure returns to 5.27 kg/cm^2 (75 psi). A drop to 1.41 kg/cm^2 (20 psi) in this system will lockout the pump and operate a red alarm light. At this time the pump can only be operated by manual resetting.

Pump No. 3 will automatically start at 4.22 kg/cm^2 (60 psi) and shut off at a rise to 7.03 kg/cm^2 (100 psi). A drop in system pressure to 2.11 kg/cm^2 (30 psi) automatically locks out the pump and operates a red alarm light. This emergency cut out condition requires manual resetting before the system can be operated again.

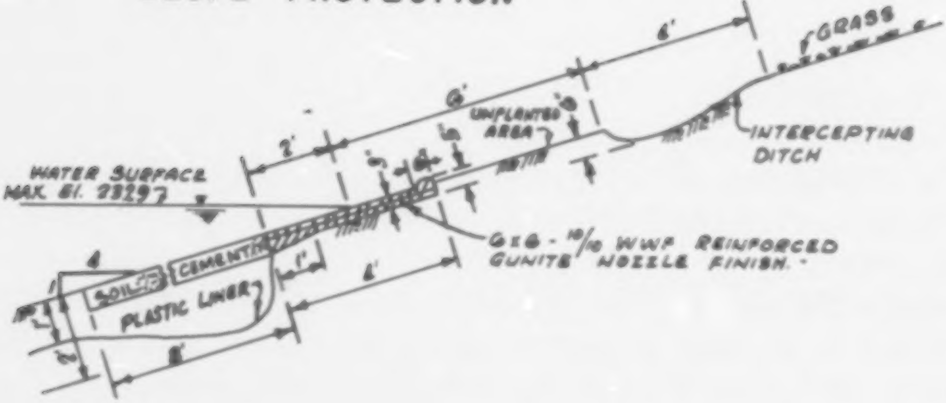
Lake Lining

Although the park site, an abandoned borrow pit, originally contained ponded water, excavation of the lakes opened sand lenses which required lining of the lakes. The lining ultimately installed was a 0.254mm (10 mil) polyethylene material with 30.48 cm (1 ft) of soil cover for puncture protection. The seaming of this polyethylene material was accomplished with waterproof pressure sensitive polyethylene tape and adhesive. To ensure against seam separation each seam was placed within a 30.48 cm (1 ft) accordian fold that consisted of 91.44 cm (36 in) of material. This was calculated to protect the liner from soil movement or earthquake action.

The liner was secured to the lake shore by lowering the liner edge 60.96 cm (2 ft) then looping it up to the surface so as to have a slug of soil as an anchor. As a seal and to increase the liner anchorage a soil cement concrete pad was placed over the liner edge and abutting against a gunited lake embankment protector as shown in Figure 20.

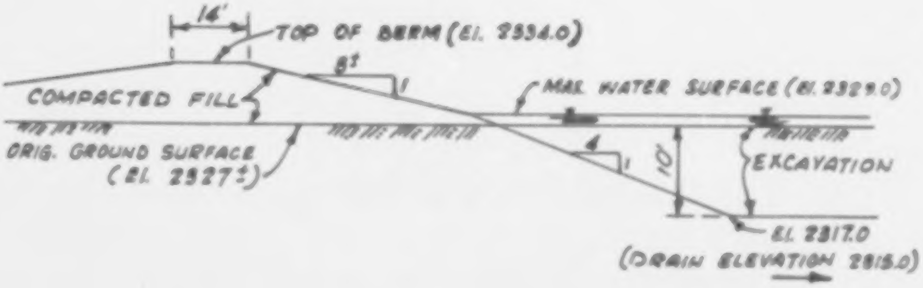
Bank Protection

For protection against bank erosion, a 1.22 m wide, 7.62 cm thick (4' x 3") wire mesh reinforced gunited concrete pad was constructed around the lake edge. Contiguous and



SLOPE PROTECTION

6'
GRASS
6'
UNPLANTED AREA
INTERCEPTING DITCH
2'
WATER SURFACE MAX. EL. 2329
6x6 - 10/10 WWF REINFORCED GUNITE NOZZLE FINISH.
4
1
SOIL
CEMENT
PLASTIC LINER
1'
6'
8'



TYPICAL CROSS SECTION OF LAKE EMBANKMENT

Figure 20 TYPICAL LAKE EMBANKMENT
AND SLOPE PROTECTION

interiorly concentric to this pad was constructed a 2.44 m (8 ft) by 15.24 cm (6") thick soil cement low water level erosion pad that also doubled as anchorage for the lake liner. (See Figure 20).

Lake Separations

Each lake can be separated from the others by closing stop-log structures that are located at lake interception points, enabling individual lakes to be drained or filled when necessary for the research and study program. This would enable the setting and maintaining of controlled environmental conditions in individual lakes and also the maintenance of a control lake for comparison purposes. The structures contain 20.32 cm x 30.48 cm (8" x 12") concrete logs that are piled on top of each other to form a seal wall. Overflow structures that connect to the natural drainings outside the park complete the lake protection devices.

Other Design Considerations

The lake embankments from the top elevation to the below water elevation consists of a lawn, swale, bare area, gunited and soil cement slope protection, and lastly, a plastic liner protected by 30.48 cm (1 ft) of soil cover.

Since the lawn contains natural and supplemented nutrients, the swale, a 1.22 m wide by 15.24 cm (4' x 6") deep ditch around the lakes, is designed to capture surface run-off that might transport these algae and weed-promoting nutrients to the lakes. Therefore, the bare area is used as a buffer zone between the lawn and lake so as to provide an area comparatively free of nutrients.

The gunited and soil cement areas are primarily for water erosion prevention, although they also provide a surface not conducive to water vegetational growth.

To prevent stagnation, the lakes have been constructed with a series of drain structures, inlets and overflows that allow free circulation of water by regulation of inflow and/or drain flow. This elimination of stagnation coupled with the vegetation control reduces the chance of insect growth.

LANDSCAPING

Plants selected for Apollo County Park were chosen not only for their tolerance to alkaline soils, but for adaptability to extremes in temperature since the area is characterized by wide swings in temperature, both between summer and winter and between day and night. In the Lancaster area winter lows of -14.4° to -17.8°C (6° to 0°F) have been recorded, although from December through February the mean daily minimum ranges from 0° to 4°C (32° to 40°F). Also, high summer temperatures above 43.3°C (110°F) have been recorded. On the average, there are 110 days with temperatures above 32.2°C (90°F) and in the winter 80 to 85 nights with temperatures below 0°C (32°F). Freezing nights are often followed by days of 15.6°C (60°F) mean temperature. Therefore, climate was one limiting factor in the selection of plants that would grow satisfactorily at the park site.

The primary hazards of the climate are late spring frost and the desert winds. If winter soil moisture is not adequate, winter wind and bright sunlight can combine to kill normally hardy evergreen plants by desiccation.

Since the area has a highly saline alkali soil, salinity and alkalinity were also important factors in choosing suitable plant species for the park. Saline soils contain an overabundance of salts, which in high concentration damages plants. Salts containing sodium or chloride are particularly injurious to ornamental plants.

Ground Cover

The lawn areas were prepared by finishing the grade without humps and hollows to enhance water drainage and by removing all roots and stones larger than 2.54 cm (1 in) in diameter. Organic fertilizer was uniformly distributed to approximately 2.54 cm (1 in) depth and disced parallel to contours 15.24 cm (6 in) into the soil. The lawn areas were floated smooth to present a neat uniform appearance and grass seed evenly drilled into the soil with a Brillion type seeder at the rate of 24.41 gm/m^2 (one pound per 200 sq. ft.). On the islands seed was distributed at the rate of 16.81 kg/ha (15 lb/ac) for Mt. Barker strain clover and 560 gm/ha (12 lb/ac) for Lupinus Blue Bonnet.

Shrubs and Trees

Trees and shrubs are known to be sensitive to salinity. However, with gypsum in the soil (to replace Na^+ and K^+ ions with CA^{++} ions) these plants will then tolerate electrical conductivity up to 4 millimhos per cm.

The special plants chosen for Apollo County Park are as indicated in Table 10.

Plant pits for shrubs were excavated three times wider than the ball width and twice as deep as the root ball height. Backfill consisted of soil from the plant pit mixed with 1.48 kg/m^3 (2½ lb/yd^3) of urea formaldehyde, 4 cans of sludge and 8 cans of redwood shavings. The measuring can being the container within which the plant was received. The pits were backfilled until the shrubs were at natural growing height after settlement. A 1.22 m (4 ft) diameter water basin was constructed around each plant. This was

Table 10

LISTING OF SPECIAL TREES AND SHRUBS USED IN APOLLO COUNTY PARK

Size	Scientific Name
18.92 l (5 gal.)	Cortaderia Selloana
" "	Dodanaea Viscosa Purpurea
" "	Juniperus Chinensis Torulosa
" "	Juniperus Chinensis Mint Julip
" "	Nandina Domestica
" "	Pinus Mugo Mughus
" "	Euonymus Japonica Grandiflora
" "	Elaeagnus Pungens
" "	Xylosma Senticosa
Flat Size	Eurymus Fortunei Coloratus
56.78 l (15 gal.)	Olea Europaea
" "	Roginia Pseudacacia
18.92 l (5 gal.)	Juniperus Chinensis Pfitzeriana
56.78 l (15 gal.)	Lagerstromia Indica
18.92 l (5 gal.)	Abelia Grandiflore
56.92 l (15 gal.)	Plantauus Acerifolia
" "	Cedrus Deodora
18.92 l (5 gal.)	Fraxinus Velutina Glabra
" "	Pyracantha Coccinea Lelandi
" "	Catalpa Bignonioides
" "	Celtis Australis
56.92 l (15 gal.)	Cupressus Glabra
" "	Melaleuca Linarifolia
" "	Pinus Halepensis
18.92 l (5 gal.)	Pistachia Chinensis
" "	Ulmus Parvifolia "Drake"
" "	Prunus Cerasifera Blireiana
56.92 l (15 gal.)	Calocedras Decurrens

accomplished by forming a 7.62 cm (3 in) high berm around the plant 1.22 m (4 ft) in diameter and filling this area with two cans of mulch. The mulch having been prepared by mixing equal parts of nitrogen stabilized standard commercial brand redwood shavings, containing 1% added nitrogen, and peat moss. Ten pounds of calcium nitrate was later mixed with each 2.83 m^3 (100 ft^3) of mulch.

Plant pits for trees were excavated 1.22 m (4 ft) square and 60.96 cm (2 ft) deep. This excavated soil that was previously reclaimed was used for backfill. An additional 30.48 cm (1 ft) was excavated from the tree pit and mixed with 12.70 kg (28 lb) of gypsum and 0.113 m^3 (4 ft^3) of sludge. The tree was centered in the pit, backfilled, staked, and mulched as described for shrubs. See Figure 21 for the typical method of planting trees. In addition, two 10.16 cm (4 in) diameter perforated pipes 91.44 cm (3 ft) long were placed vertically in the pit and filled with gravel to aid in watering.

All lawn areas were seeded with the grass seed mixture shown in Table 11.

Irrigation

Irrigation water is pumped from the lakes as needed depending upon the season by clock-regulated area valves. The opening of an area valve activates a pressure-sensitive switch that at a drop in water pressure to 5.98 kg/cm^2 (85 psi), starts the irrigation pump and shuts it off at 8.44 kg/cm^2 (120 psi). For safety reasons, should fire hydrant demand cause the system pressure to drop below 3.87 kg/cm^2 (55 psi), all sprinkler control panels are automatically shut off and continue to be off until the pressure returns to 5.27 kg/cm^2 (75 psi). A pressure drop

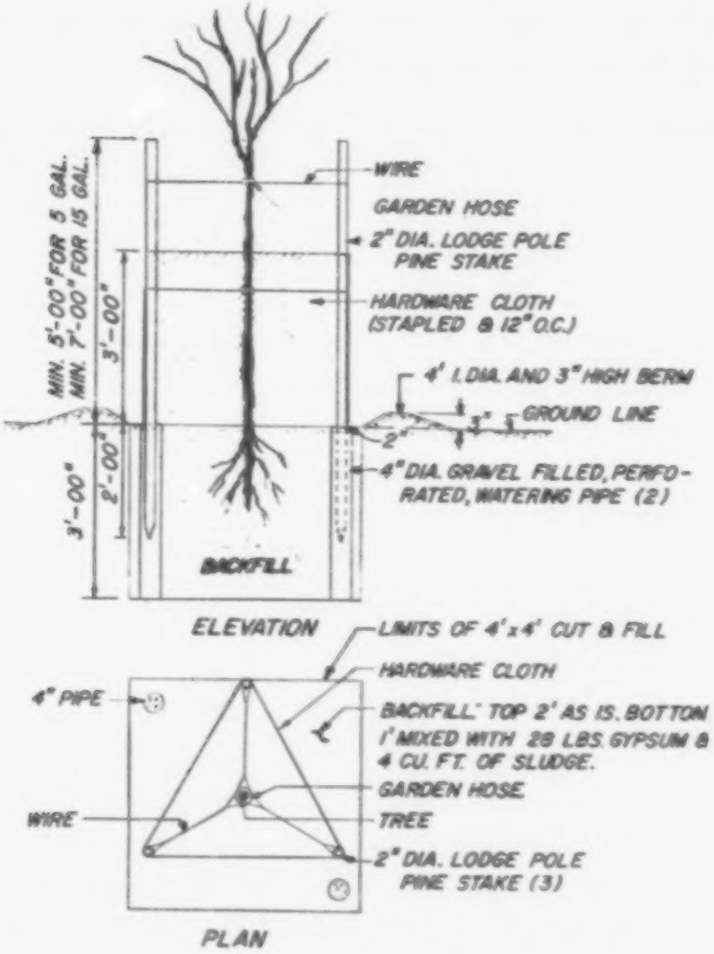

MIN. 5'-00" FOR 5 GAL.
MIN. 7'-00" FOR 15 GAL.
3'-00"
2'-00"
3'-00"
WIRE
GARDEN HOSE
2" DIA. LODGE POLE PINE STAKE
HARDWARE CLOTH (STAPLED @ 12" O.C.)
4' I. DIA. AND 3" HIGH BERM
3"
3"
GROUND LINE
2"
4" DIA. GRAVEL FILLED, PERFORATED, WATERING PIPE (2)
BACKFILL
ELEVATION
LIMITS OF 4'x4' CUT & FILL
HARDWARE CLOTH
4" PIPE
BACKFILL: TOP 2' AS IS. BOTTOM 1' MIXED WITH 28 LBS. GYPSUM & 4 CU. FT. OF SLUDGE.
GARDEN HOSE
WIRE
TREE
2" DIA. LODGE POLE PINE STAKE (3)
PLAN

Figure 21 TYPICAL METHOD OF PLANTING TREES
(High Wind and Adverse Soil Conditions)

Table 11 LAWN SEED FOR PARK

Name	Proportion By Weight	Purity	Germination
Red Top	20%	92%	85%
Bermuda	20	98	85
Kentucky Blue	30	85	75
Newport Blue	30	98	87

to 1.406 kg/cm^2 (20 psi) activates an emergency alarm light and locks out the pump.

Water from the pump is first put through a strainer and sand extractor unit. This unit consists of a 20.32 cm (8 in) diameter semi-steel housing with a 2.38 mm (3/32") monel strainer and a 20.32 cm (8 in) centrifugal type sand separator. Then the water courses through 20.32 cm (8 in) main feeders to 10.16 cm (4 in) secondary feeders that are controlled by five independent sprinkler control panels. Each panel controls the irrigation of a portion of the park and contains individual timed circuits which control irrigation in sub-sections.

Sprinkler heads, approximately 335, are protected at critical points with vertical check valves and are of the rotating pop-up variety.

ON SHORE RECREATIONAL FACILITIES

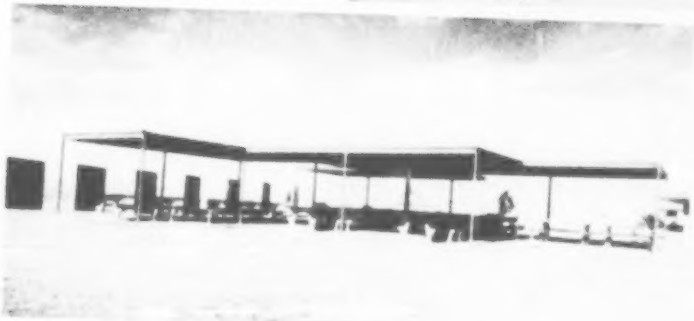
Development around the lakes includes an Apollo 11 Capsule, picnic areas, playgrounds, camping, hiking, and wildlife viewing. See Figure 14 for the development plant of Apollo County Park and the locations of these facilities. Park facilities are pictured in Figures 22 and 23.

Apollo 11 Capsule Building

On December 31, 1971, the Los Angeles County Board of Supervisors made a request for a five-year loan of the "Apollo Command Module True-Size Replica" from the Smithsonian Institution for display at the Apollo County Park. This request was granted and in 1973, upon completion of a suitable structure to house it, the module was transported from the Downey, California, North American-Rockwell plant, where it was stored. This structure was designed to provide the necessary security, maintenance

CONCESSION
BUILDING

PUMP AND
CONTROL
BUILDING



TYPICAL
MULTIPLE
PICNIC SHELTER

FISH CLEANING
BUILDING

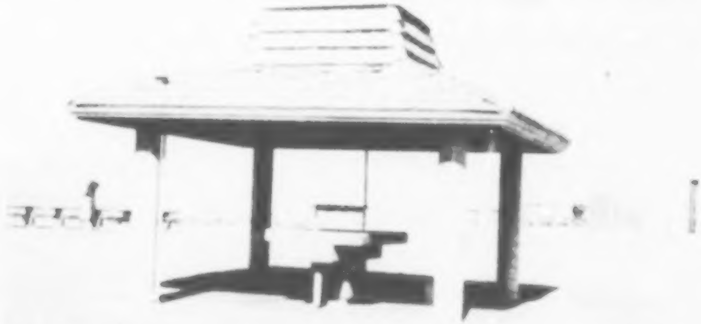
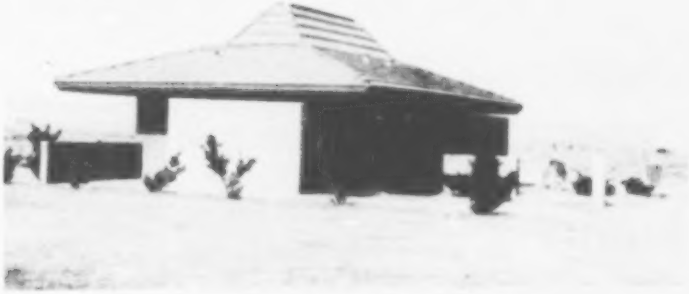


Figure 22 PARK FACILITIES

ENTRANCE
SIGN

ENTRANCE
and
SERVICE
BUILDING



TYPICAL
RESTROOM

TYPICAL
PLAYGROUND

Figure 23 PARK FACILITIES

against deterioration, destruction, or damage, and the maximum display of the module. (See Figure 24).

Picnicking Facilities

Picnic facilities are divided into family and group types. Basically each is a pergola consisting of a cluster of 4.57 m by 4.57 m (15' x 15') shelters containing picnic tables. The family picnic pergola consists of three shelters arranged to form an ell. The group picnic pergola contains groups of shelters in lots of 7, 8, or 9. The shelter is constructed by placing tinted asbestos-bonded galvanized steel V-beam sheets over roof beams that are connected to columns over a concrete slab.

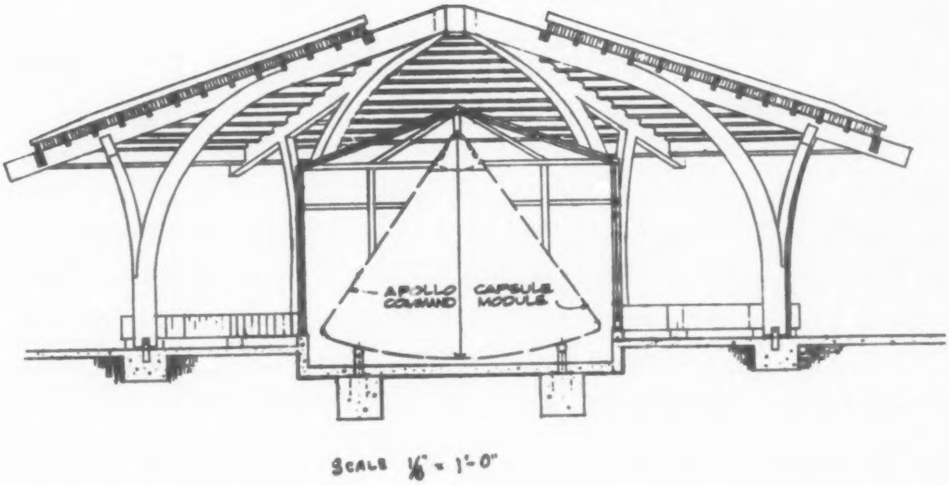
Picnic tables within the pergolas are constructed of Douglas Fir and concrete. Concrete is used for the table legs while varnished Douglas Fir 7.62 cm x 20.32 cm x 2.13 m (3" x 8" x 7') planking is used for table surface and seating purposes. Each pergola is serviced with pipe mounted barbecue stoves and trash containers.

Camping Areas

Apollo County Park contains two overnight camping areas. These areas are located in the center of the park between the lakes and cover approximately 1.01 ha (2½ ac). Daylight camping is allocated on first come basis but overnight camping is by reservation only. Each campsite is serviced with barbecues, tables, and trash containers.

Playgrounds

As shown on Figure 15, Development Plan, Apollo County Park, the three playgrounds are constructed in the park and they are based on space travel, pioneer, and nursery rhyme themes. All playgrounds contain arch swings. The space travel playground has a geodesic climber, rocket, scout



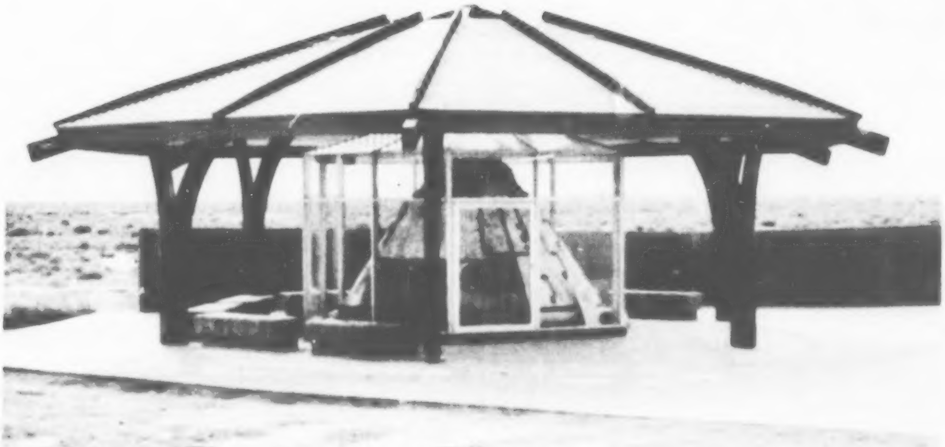


Figure 24 APOLLO CAPSULE COMMAND MODULE
AND BUILDING AT PARK SITE

rocket, and radar tower. The pioneer playground has a prairie schooner, corral, frontier outpost, and a cactus climber. The nursery rhyme playground has a superbug, billy goat gruff, spider climb, old-woman-in-the-shoe, and a scarecrow swing.

Amphitheater

An amphitheater has been constructed to provide an area for groups to give plays, recitals, or hold meetings. This amphitheater makes use of a lawn slope for seating purposes. Audience seating is for approximately 200 people and the stage provides a 253.15 m^2 (2,725 ft^2) concrete slab floor work area. Two-thirds of the stage front is available for presentations while the back one-third is used as a screened area for stage preparations. Other features are a fire pit and a concrete block dividing wall with flagpole, banner, and torch inserts.

WATER SPORTS--AQUATIC RECREATION

Aquatic recreation at Apollo County Park is limited to non-body contact water activities at this time. These include a ferry raft ride, boating, and sport fishing. Each of these facilities is discussed in detail in the following paragraphs.

Raft

For the enjoyment of the children and also for transportation to the most southeasterly island in Lake Mike Collins, a 5-man capacity Tom Sawyer type raft has been constructed with docking ramps and tow rope. The ramps are float-mounted and therefore adjust automatically to rising or lowering of the lake level. Six life rings are provided for safety purposes, two on each ramp and two on the raft. Also security gates are provided on the raft and ramps, and an emergency paddle for propulsion should the two ropes fail. See Figure 25.

Boating

Accommodations for a maximum of 70 boats have been provided for the lakes. All boats are to be furnished by a concessionaire. These boats can be canoes, paddle wheelers, rowboats, or sailboats. No boat with a motor is permitted on the lakes. A concession building is provided for the maintenance and operation of the boating concession.

A boat dock with capacity for tying up 70 boats is located on the westerly shoreline of Lake Edwin "Buzz" Aldrin. See Figure 26, Boat Dock Facilities at Park. The boat dock is a tee-shaped concrete pontoon structure with concrete slab walk surface. Six concrete piles secure the boat dock from drift and a boarding ramp provides access.

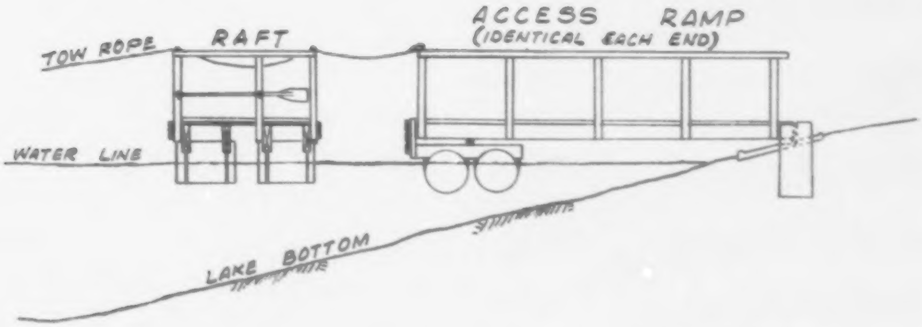
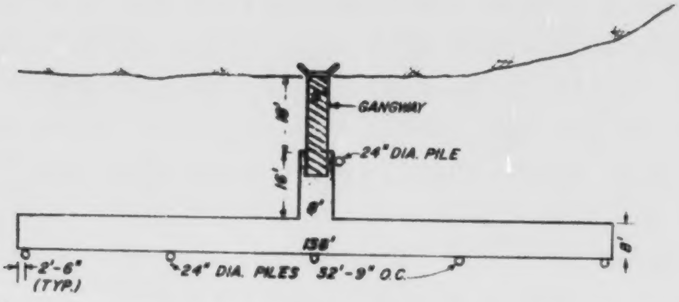


Figure 25 FERRY RAFT AND ACCESS RAMP AT PARK



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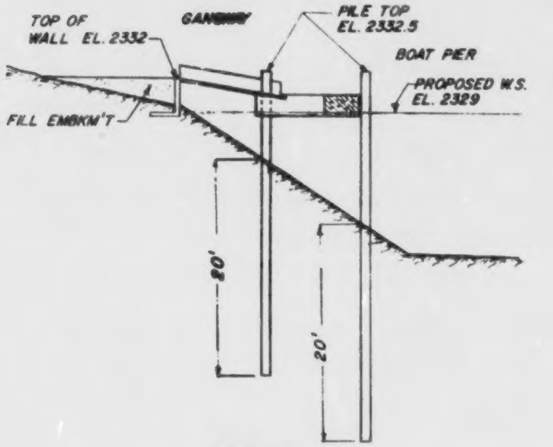

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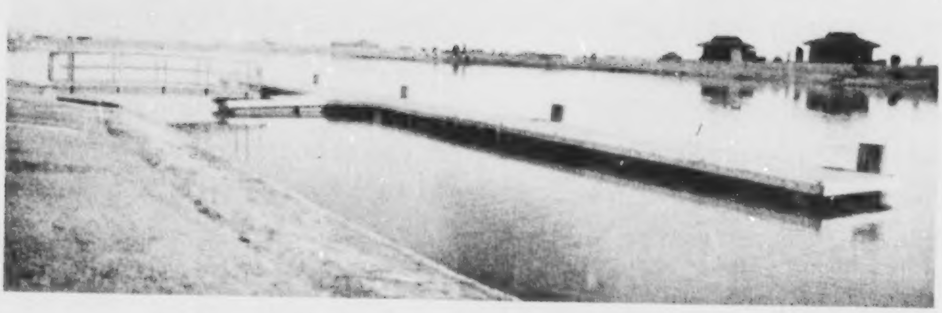


Figure 26 BOAT DOCK FACILITIES AT PARK

Fishing

One of the more important aspects of the overall project was to provide a renovated wastewater quality which would support a sport fishing program. The fishing program recommended by the California Department of Fish and Game was to introduce warm water fish such as bass, sunfish, and catfish which would reproduce and maintain themselves. Also, to supplement the native fish, it was planned to plant trout in the colder months and catfish in the warmer months. This plan would support a good year-round fishing program and draw people to the park facilities.

To maintain a native warm water fish population, it was necessary to provide special fish shelters, hideaways, and spawning areas. The location and types of these facilities are shown on Figure 27. It was also necessary to install adequate fish screening facilities at pumping and flow regulation structures. In addition, the California Department of Fish and Game recommended that to ensure the survival of the young fish, aquatic plants should be maintained in certain locations.

As soon as water was available in two of the lakes, which was in early 1971, the initial planting of adult fish took place. These consisted of 100 Largemouth Black Bass, 50 Red-Ear Sunfish, and 20 Channel Catfish. To determine if trout could survive in such waters, especially during the warmer summer months, 100 small Rainbow Trout were introduced to the lakes in December, 1971. An additional planting took place in March of 1973 and consisted of 5,200 baby Channel Catfish. This information is tabulated in Table12, which also shows the average length and weight of the fish.

It was determined that a fishery could be maintained in the lakes sufficient to make available for harvest each year at

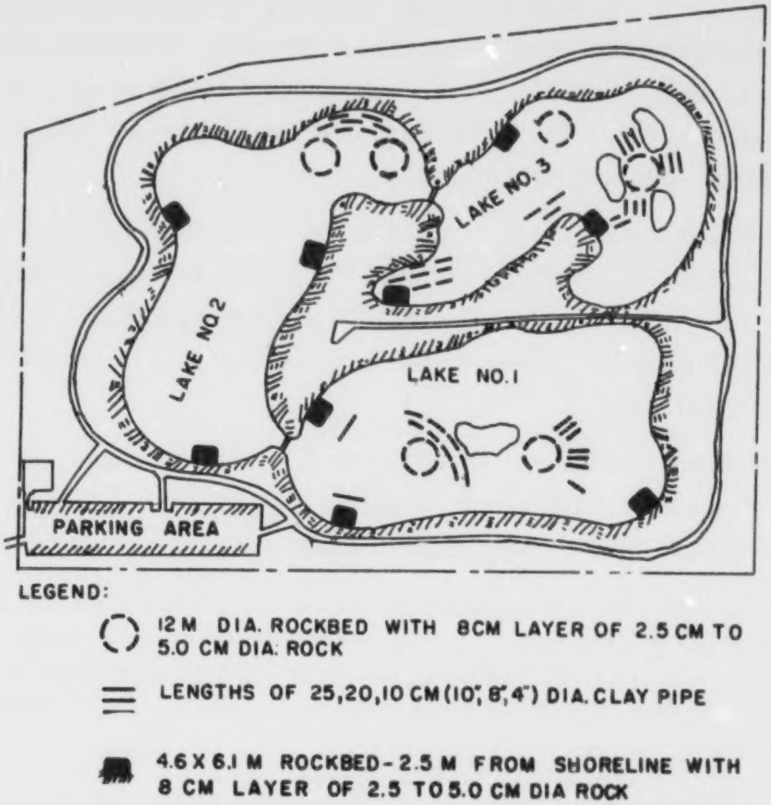

LAKE NO. 3
LAKE NO. 2
LAKE NO. 1
PARKING AREA
LEGEND:
12 M DIA. ROCKBED WITH 8CM LAYER OF 2.5 CM TO 5.0 CM DIA. ROCK
LENGTHS OF 25,20,10 CM (10", 8", 4") DIA. CLAY PIPE
4.6 X 6.1 M ROCKBED - 2.5 M FROM SHORELINE WITH 8 CM LAYER OF 2.5 TO 5.0 CM DIA ROCK

Figure 27 SPECIAL FISH HABITAT FACILITIES

Table 12 FISH STOCKED IN
APOLLO COUNTY PARK RECREATIONAL LAKES

Type	Date	Average length (cm)	Average Weight (gms)	Number of Fish
Largemouth Black Bass (Micropterus Salmoides)	3-16-71	30.5-35.6	350	100
Red Eared Sunfish (Leapomis Microlophus)	3-3-71	15.2	90	50
Channel Catfish (Ictolurus Punctatus)	3-3-71 3-3-71	40.6-50.8	1010	20
Rainbow Trout (Salmo Irideus)	12-22-71	10.2-15.2	70	100
Channel Catfish (Ictalurus Punctatus)	3-1-73	10.2-15.2	65	5200

least 2495 kgs (5,500 lbs) of Channel Catfish, 45 kgs (100 lbs) of Largemouth Black Bass and Red-Ear Sunfish per surface acre, and 0.45 kg (1 lb) of Rainbow Trout for each trout angler-day. To maintain such a fishery, the following program was established.

1. Plant trout of a catchable size, including some fish of over one pound to provide additional angler interest. At least 9750 kgs (21,500 lbs) of trout should be planted each year to maintain this program.
2. Plant catfish of catchable size to supplement the native stock. At least 2495 kgs (5,500 lbs) of catfish to be planted each year.
3. Plant other warmwater fish as necessary to maintain the fishery.
4. Plant, as necessary, natural fish food sources.
5. Construct additional fish environmental facilities, if required, to maintain the warmwater fishery.

All fish planted were recommended by the California Department of Fish and Game because of their propagation abilities (other than Rainbow Trout), fast growing and survival rates, and their good eating qualities.

Minnows (Gambusia) were also introduced to the lakes as a food source for the larger fish and to help regulate insects. However, the lake's support of natural food sources, especially daphnia among the several crustaceans, is sufficient for the fish.

To enhance the sport of fishing, the park is provided with a floating fishing pier, fish-cleaning building, and concession building for the sale of bait and fishing equipment, food, and boat rentals.

The fishing pier as shown in Figure 28 is constructed in the same manner as the floating boat dock, but the entire perimeter is fenced in with a handrail for safety purposes.

The fish-cleaning building, an open structure with red clay tile roof, provides a means for cleaning fish and disposing of fish garbage. See Figure 22, for a photograph of this structure.

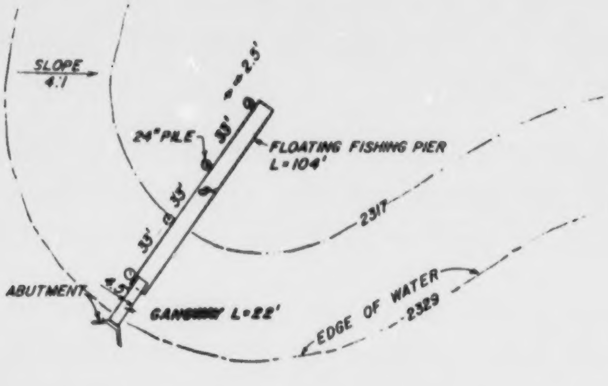
Refer to Section VIII for further information on the results of the fishing program.

MISCELLANEOUS CONSTRUCTION

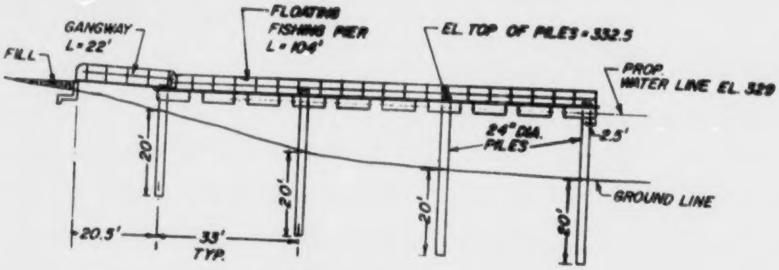
Drinking Fountains

Potable water for the park is secured from the water supply system of General William J. Fox Airfield. The potable water conveyance system, consisting of approximately 1060 m (3500 ft) of 15.24 cm (6 in) diameter asbestos cement pipe delivers water to the park.

Drinking fountains were provided and are strategically located throughout the park. These fountains are connected to the on-site domestic water supply system consisting of approximately 2100 m (7,000 ft) of 10.66 cm (4 in) diameter asbestos cement. Each drinking fountain contains a faucet for filling of canteens, cups, and pails. For details, see Figure 29. The drinking fountains were placed so that irrigation water (renovated wastewater) would not come in contact with them for further public protection.



PLOT PLAN



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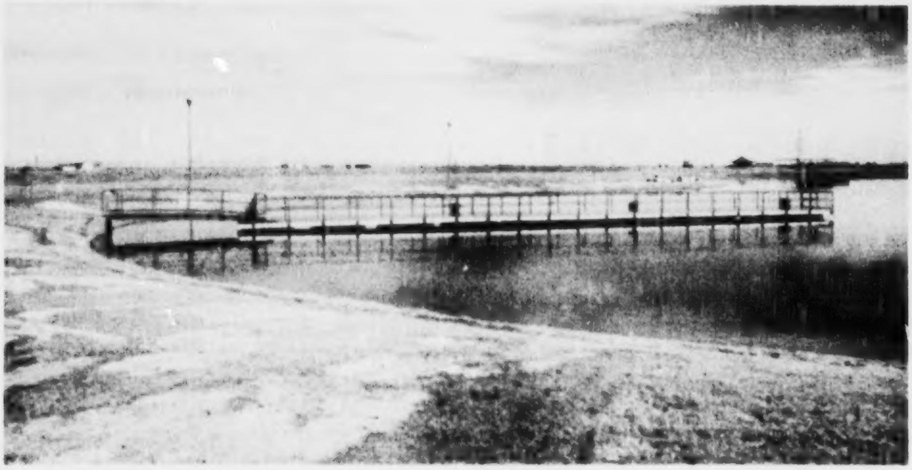


Figure 28 FISHING PIER AT PARK

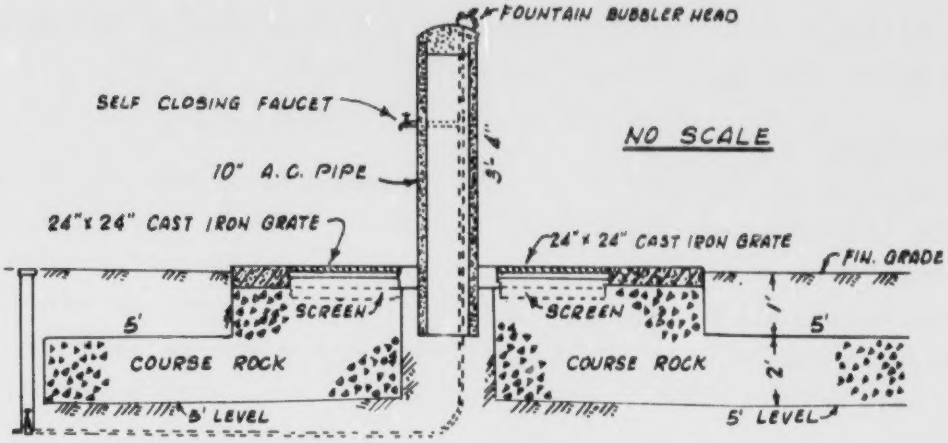


Figure 29 TYPICAL DRINKING FOUNTAIN AT PARK

Sanitary Facilities

In addition to the restrooms provided in both the service building and the concession building, six comfort stations were constructed for public use. These stations were constructed of tinted concrete block and have overhang style red clay tile roofing. Serving these facilities are the domestic water supply system as described under drinking fountains, and the on site sewage system. The sewage system consists of 1130 m (3700 ft) of 20.32 cm (8 in) diameter vitrified clay pipe which connects to a 38.10 cm (15 in) off-site sewer that ultimately outlets to the Sanitation District No. 14 trunk sewer system.

Fire Protection

Fire protection for park facilities is afforded by Fire hydrants located every 152.40 m (500 ft) or less along the interior road. These hydrants are connected to the park irrigation system which draws water from the lakes by means of the pumping facilities as described previously. This fire protection system was designed and constructed in compliance with the requirements and regulations of the Los Angeles County Forester and Fire Warden.

Lighting

Lighting of the park area is accomplished by use of 250 and 400 watt mercury vapor lamp fixtures. These lamps are controlled by time switches housed in a weatherproof switchboard located at the comfort station just north of the Pump Control Building. All lamp fixtures are spaced approximately 73 m (240 ft) apart and are 5.79 m, 7.62 m, or 9.14 m (19', 25', or 30') high with 1.22 m (4 ft) arms.

Roadways, Parking Lot and Walkways

As a part of the park development, an access road from the entrance of Gen. William J. Fox Airfield to the Park entrance was constructed. This road is approximately 960 m (3150 ft) long and 7.31 m (24 ft) wide and was constructed of 5.08 cm (2") asphaltic concrete on 20.32 cm (8") of aggregate subbase. Additionally, approximately 2040 m (6,700 ft) of interior roads were constructed along the lakes as indicated on Figure 15. These interior roads are 3.66 m (12 ft) wide and consist of 5.08 cm (2") asphaltic concrete on 7.62 cm (3") gravel base, placed between 15.24 cm x 15.24 cm (6" x 6") concrete headers. Walkways to facilities such as the concession building, the fishing pier, the boat dock and the capsule building are also provided. They were constructed of the same material as the interior roads.

The parking lot, located at the park entrance, provides 196 parking spaces. It is constructed of 7.62 cm (3") asphaltic concrete on 15.24 cm (6") rock base. An additional unpaved parking area located at the northeast corner of the park site has been reserved for future parking.

SECTION VI
DETAILED CONSTRUCTION AND RESEARCH COST DATA

GENERAL

The total cost of the Antelope Valley Waste Water Reclamation Project consists of four basic components:

1. Renovated Water Conveyance System--A pipeline to carry the renovated water from the tertiary treatment plant to Apollo County Park (2 contracts).
2. Tertiary Treatment Plant--An additional treatment facility located at the County Sanitation District No. 14 Site (1 contract).
3. Apollo County Park--Complete development of an aquatic park (6 contracts).
4. Research and Development--Pilot plant, soil reclamation, fish pathology and other studies performed from 1964 through 1968 and the final research at the full-scale demonstration facilities from 1964 through 1973.

The location of the various facilities is shown on the map, Figure 3.

Nearly all of the contracts involved were "lump sum" and, therefore, actual component costs cannot be determined. However, where these cost breakdowns are known and meaningful, they are indicated.

Figure 6 indicates the construction contracts involved, the length of time for each contract, and the construction contract cost. Table 13 is a summary of engineering, construction and research costs.

Table 13 COST SUMMARY

	Engineering		Construction		Total	
	$	%	$	%	$	%
TERTIARY TREATMENT PLANT	36,455.15	1.9	222,450.82	8.9	258,905.97	10.8
RENOVATED WATER CONVEYANCE SYSTEM	7,840.32	0.3	119,362.45	5.0	127,202.77	5.3
APOLLO COUNTY PARK	230,581.67	9.3	1,768.433.19	74.6	1,999,014.86	83.9
TOTAL FACILITY COSTS*	274,877.14	11.5	2,110,246.46	88.5	2,385.123.60	100
TOTAL RESEARCH AND DEMONSTRATION COSTS	481,000.00		-0-		481,000.00	
TOTAL PROJECT COSTS*	755,877.14	26.4	2,100.246.46	73.6	2,866,123.60	100

*Overhead costs of $79,876.20 not included

Engineering and incidental costs shown in the following cost data include Administration, Supervision, Design, Specifications, Contract Preparation, Surveys and Inspection.

RENOVATED WATER CONVEYANCE SYSTEM

Phase I - January to April 1968

Construction of 2185.42m of 30.48 cm
(7170 feet of 12-inch) Asbestos Cement
Pipe with all appurtenances.

Contract Cost	$51,810.45
Engineering and Incidentals	4,859.26

PHASE II- May to October 1968

Construction of 4213.86m of 30.48cm
(13,825 feet of 12-inch) Asbestos Cement
Pipe with all appurtenances.

Contract Cost	$ 67,552.00
Engineering and Incidentals	2,981.06
Total Cost of Renovated Water Conveyance System	$127,202.77

TERTIARY TREATMENT PLANT

Construction from May 1968 to August 1969 of a
Tertiary Treatment Plant, including Reinforced
concrete Structures, Concrete-lined Ponds,
Frame and Stucco Building, and all Equipment.

Contract Cost	$222,450.82
Engineering and Incidentals	36,455.15
Total Cost of Tertiary Treatment Plant	$258,905.97

APOLLO COUNTY PARK

General Development - Phase I
April 1969 to April 1972

Lake Excavation, Gunite Bank Protection,
Fish Spawning Beds, Initial Soil Reclamation.

Contract Cost	$359,631.59

Pump House, Pumps and Motors,
Control Piping, Stop Log and
Drain Control Structures

Contract Cost	$148,170.00

Sprinkler and Fire Fighting Systems, Roadways and Parking Lot, Fencing, Initial Landscaping including Landscaping Rock, and Electrical Work

Contract Cost	$185,899.24	
Total Contract Work		$693,700.83
Engineering and Incidentals		85,856.66

Off-Site Interceptor Sewer- May 1970 to September 1971

Construction of 3352.80m of 38.10, 45.72, 53.34 and 60.96 cm (11,032 feet of 15-, 18-, 21- and 24-inch) Vitrified Clay Pipe Interceptor Sewer with all Appurtenances

Contract Cost		$118,419.57
Engineering and Incidentals		20,973.94

General Development - Phase II - June 1970 to September 1971

Service Building and 6 Comfort Stations

Contract Cost	$128,812.26	

31 Security lighting poles and Electrical Work

Contract Cost	$ 65,634.40	

Park Sewerage System and Domestic Water System

Contract Cost	$ 90,688.63	

Entrance Road and Parking Lot Completion

Contract Cost	$141,437.27	

Masonry Walls, Fencing, Concrete Walks and 7 Drinking Fountains

Contract Cost	$ 15,959.23	
Total Contract Cost		$442,531.79
Engineering and Incidentals		32,442.57

Lake Sealant - September 1970 to January 1971

Installation of earth covered plastic membrane around all lakes

Contract Cost		$106,538.00
Engineering and Incidentals		4,224.73

General Development - Phase III - October 1971 to December 1972		
Fishing Pier, Boat Dock and Ferry Raft		
Contract Cost	$ 33,500.00	
Final Landscaping, Soil Reclamation, Sprinklers, Park Signs, Amphitheater, Fish Cleaning Building and Miscellaneous		
Contract Cost	$135,348.46	
3 Playgrounds, Wind Barricades and 60 Picnic Pergola Units Equipped		
Contract Cost	$121,741.50	
Total Contract Work		$290,589.96
Engineering and Incidentals		69,706.18
General Development - Final Phase - April to December 1972		
Concession Building, Apollo Capsule Building, Additional Security Fencing, and Final Site Work		
Contract Cost		$116,653.04
Engineering and Incidentals		17,377.59
Total Cost of Apollo County Park		$1,999,014.86
RESEARCH COSTS		
Initial Research and Pilot Facilities		
Construction of pilot treatment plant processes, bacterial and viral tests, fish pathology studies and facilities, soil reclamation studies, waste water quality standards (1964 to 1969)		$299,000.00
Final Research and Testing		
Research, testing and demonstration on full-scale facilities, water quality, lake performance, continued bacterial and viral studies, fishing program, algae and soils studies, public acceptance (1969 to 1974)		$182,000.00
Total Research Costs		$481,000.00

SECTION VII
DEMONSTRATION AND EVALUATION OF TERTIARY TREATMENT PLANT

INTRODUCTION

After the tertiary treatment plant was completed and placed into operation, a comprehensive testing and demonstration program was conducted. The objectives of this program were to: (1) determine the operational methods needed for optimum performance, (2) study the characteristics of the alum sludge produced by the tertiary treatment plant and its effect on the main wastewater treatment plant (to which the alum sludge is returned), (3) learn if any modifications to the treatment plant were needed for the successful operation of the tertiary treatment plant and recreational lake system and, (4) assemble data on the economics of the tertiary plant operation.

OPTIMUM PERFORMANCE STUDIES

The optimization study was part of the full scale demonstration and testing program for the Tertiary Treatment Plant (TTP).

The design for the tertiary treatment process was based on an 18-month pilot plant study conducted at the treatment plant site during 1964-1966. (Final Report, Wastewater Reclamation Project for Antelope Valley[3]). The study was conducted to determine the most economical method of renovating District 14 Water Renovation Plant (W.R.P.) oxidation pond effluent to a level suitable for use in recreation lakes to be located in Antelope Valley. The basic process flow diagram is shown in Figure 9 .

The full scale 1900 m^3/day (0.5 mgd) tertiary plant, constructed on the District 14 W.R.P. site, and previously described in Section IV, was put into service in June, 1969. Influent to the TTP is supplied by the District 14 W.R.P., which consists of primary sedimentation followed by 27.1 hectares (240 acres) of oxidation ponds. Solids are treated by two anerobic digesters and are dewatered in sludge dewatering beds.

The pilot plant feed used in the original research study was obtained from Oxidation Pond No. 3 which received approximately 45-60 days of detention time treatment. The full scale TTP influent is drawn from Oxidation Pond No. 1 which receives approximately 60-120 days of detention time treatment. The differences in influent characteristics between the pilot study and the present operation of the TTP are partially a result of this additional detention time in the ponds. The differences are discussed later in this report.

The TTP effluent was required to meet the following basic specifications for discharge into the lakes:

Parameter		Level
PO_4	less than	0.5 mg/l
Ammonia N	" "	1.0 mg/l
Turbidity	" "	5.0 JTU

The TTP was designed to remove both PO_4 and turbidity from the oxidation pond effluent. Ammonia is not removed by the process. A summary of the design factors for the TTP is shown in Table 2.

Study Objectives

The primary objective of the study was to determine the optimum flocculation pH for producing water which met the effluent discharge criteria and minimized costs. Analysis of the operational characteristics of the TTP also was an objective. Comparisons between full scale actual operation and the TTP design parameters were to be made where possible.

To accomplish the objectives outlined above, it was decided that the efforts to optimize plant operation should be carried out at the design flow of 1900 m^3/day (0.5 mgd).

Data Collection

Data for use in the optimization study was collected during the period from October, 1971 through December, 1972. This time interval was of sufficient duration to cover the complete seasonal cycle of oxidation pond operation and resulting fluctuations in the influent characteristics to the TTP. Various influent, effluent, and process characteristics were monitored as listed in Table 14.

Table 14

TERTIARY TREATMENT PLANT MONITORED CHARACTERISTICS FOR OPTIMIZATION STUDY

CHARACTERISTIC	PLANT INFLUENT	FLOCCULATION CHAMBER	SEDIMENTATION TANK EFFLUENT	PLANT EFFL.
Temperature	X			
Flow Rate	X			X
pH	X	X		
Total Alkalinity	X			
Total Phosphates	X			X
Susp. Solids	X		X	
Alum Dose		X		
Chlorine Dose	X			X
Turbidity				X
Ammonia - N	X			
Algae Counts	X			

Influent Characteristics

The influent water temperatures are plotted in Figure 30 and ranged from a low monthly average of 5°C (41°F) in January, to a maximum monthly average of about 21.7°C (71°F) in August. The annual average was approximately 12.2°C (54°F).

The suspended solids data collected during the period of study are shown in Figure 30 and values ranged from a low monthly average of about 72 mg/l during November (1971) and January (1972), to a maximum monthly average of 140 mg/l in August. The annual average suspended solids concentration was 99 mg/l. Changes in influent suspended solids levels resulted primarily from two mechanisms. Increased biological growth, as the pond temperature and sunlight intensity increased seasonally, were clearly apparent in the monthly averages. Another factor which caused changes in the influent suspended solids concentration was wind mixing. High winds caused the contents of the ponds to be mixed and solids increased significantly. In one instance during the study, high winds caused the influent suspended solids to the TTP to increase by a factor of approximately 4, and resulted in deterioration of the effluent with respect to PO_4 and turbidity.

Feed pond (No. 1) algae counts are illustrated in Figure 31. Two of the fresh water divisions for algae classification are represented. These algae, blue-greens and greens, were common to the feed pond during the period of study. During blue-green predominance from February through July, the blue-green counts were as high as 420,000 cells/ml (March-April). The green algae were predominant from October (1971) through January (1972), and July through October (1972). Green counts were at a maximum of 275,000 cells/ml in October of 1971.

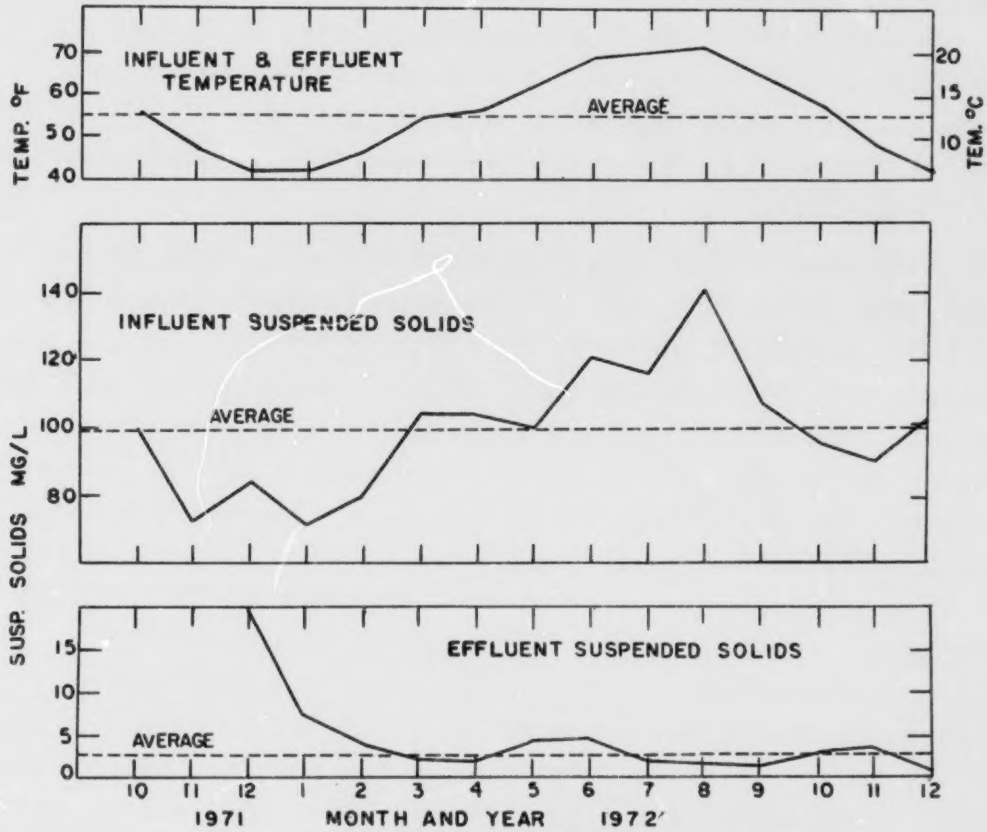


Figure 30 TERTIARY TREATMENT PLANT SUSPENDED SOLIDS AND TEMPERATURE LEVELS

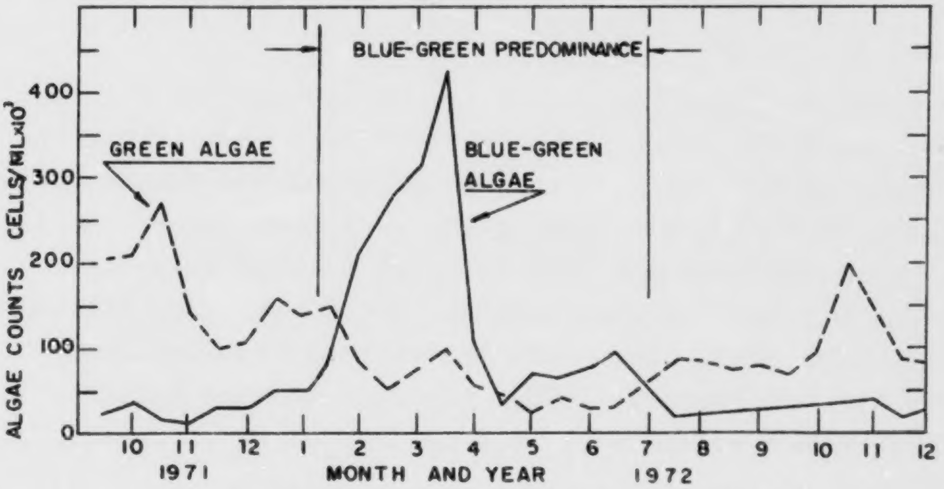


Figure 31 FEED POND ALGAE COUNTS

The predominance of blue-green algae during the spring and summer was probably a result of the low nitrogen waters in pond No. 1. Blue-green algae thrive in low nitrogen waters which are allowed to stand, because they fix nitrogen from the atmosphere. The green algae require lots of nitrogen to grow and, therefore, only predominate in waters that can adequately supply the necessary nutrients. Recirculation of water between the oxidation ponds seemed to aid in obtaining a reduced quantity of blue-green algae late in the study.

The blue-green algae predominance caused numerous operational difficulties during the study. The blue-green caused a reduction of TTP effluent production because the Oscillatoria algae did not flocculate well. Increased alum dosage was required and the filamentous algae infiltrated the filter media. The infiltration caused high effluent turbidity and PO_4 concentrations and increased the frequency of backwashing. During these difficult operating periods, it was necessary to reduce the flow to produce an acceptable effluent. A green algae, Euglena, also caused problems because they tended to pass through the filter. Prechlorination corrected this because it caused the Euglena to "ball up" and be removed by the filter.

Influent ammonia levels expressed as N. were essentially zero during the optimization study with exception of short periods in March and September of 1972. During these brief instances, ammonia concentrations of about 2 mg/l were present. Influent phosphate concentrations ranges from 22 mg/l to 36 mg/l during the period of study. The annual average phosphate concentration was 31 mg/l. For more detail on the influent ammonia and phosphate levels, refer to Table 15 and Figure 32.

Table 15

AVERAGE WATER QUALITY CHARACTERISTICS FOR MARCH, APRIL, MAY, 1971 and 1972

CONSTITUENT	Units	Tertiary Plant Influent	Tertiary Plant Effluent	Apollo Lakes
Temperature	^oF	57	59	58.2
Turbidity	JTU	41	1.45	10.1
pH	pH	9.09	6.51	8.64
Total Diss. Solids	mg/l	653	630	817
Suspended Solids	mg/l	89.5	2.0	11.4
Alkalinity	mg/l $CaCO_3$	236.3	74.0	134.5
Boron	mg/l B	1.13	1.04	1.23
Carbon Dioxide	mg/l CO_2	0	48.87	1.07
Chlorine Demand/hr	mg/l Cl	2.16	0	0.87
Chlorine Residual	mg/l Cl	0	2.33	0
Total Hardness	mg/l $CaCO_3$	64	63	103
MBAS	mg/l LAS	0.100	0.100	0.160
Ammonia Nitrogen	mg/l N	0.6	0.3	0.9
Organic Nitrogen	mg/l N	11.4	1.3	1.4
Nitrite Nitrogen	mg/l N	0.21	0.01	0.03
Nitrate Nitrogen	mg/l N	0.8	0.8	2.7
BOD	mg/l O	21.9	2.2	1.6
Total COD	mg/l O	186.8	38.0	41.0
Dissolved Oxygen	mg/l O	8.4	8.8	8.83
Ortho Phosphate	mg/l PO_4	27.75	0.07	0.34
Total Phosphate	mg/l PO_4	30.75	0.16	0.47
Potassium	mg/l K	17.5	16.5	18.3
Sodium	mg/l Na	179	171	167
Sodium Equiv. Ratio	% Na	81.8	81.6	78.5

Table 15 (Continued)

AVERAGE WATER QUALITY CHARACTERISTICS
FOR JUNE, JULY, AUGUST, 1971 AND 1972

CONSTITUENT	Units	Tertiary Plant Influent	Tertiary Plant Effluent	Apollo Lakes
Temperature	°F	70.4	71	70.8
Turbidity	JTU	61	2.1	12.2
pH	pH	9.43	6.58	8.33
Total Disslv.Solids	mg/l	698	699	961
Suspended Solids	mg/l	125.9	3	15.3
Alkalinity	mg/l $CaCO_3$	256.	86	149.6
Boron	mg/l B	1.03	1.005	1.34
Carbon Dioxide	mg/l CO_2	0	67.74	3.90
Chlorine Demand/hr	mg/l Cl	3.61	0	0.98
Chlorine Residual	mg/l Cl	0	1.44	0
Total Hardness	mg/l $CaCO_3$	60.4	60.7	120
MBAS	mg/l LAS	0.100	0.117	0.123
Ammonia Nitrogen	mg/l N	0.06	0.07	0.48
Organic Nitrogen	mg/l N	14.5	1.82	1.40
Nitrite Nitrogen	mg/l N	0.03	0.008	0.106
Nitrate Nitrogen	mg/l N	0.23	0.17	4.13
BOD	mg/l O	54.47	3.13	2.33
Total COD	mg/l O	216.4	44.85	50.27
Dissolved Oxygen	mg/l O	8.3	6.67	7.17
Ortho Phosphate	mg/l PO_4	30.7	0.17	0.15
Total Phosphate	mg/l PO_4	33.8	0.40	0.48
Potassium	mg/l K	17	16	21
Sodium	mg/l Na	185	175	177
Sodium Equiv. Ratio	% Na	83.1	82.3	79.2

Table 15 (Continued)
AVERAGE WATER QUALITY CHARACTERISTICS
FOR SEPTEMBER, OCTOBER, NOVEMBER, 1971 AND 1972

CONSTITUENT	Units	Tertiary Plant Influent	Tertiary Plant Effluent	Apollo Lakes
Temperature	^{o}F	50.6	57.1	55.6
Turbidity	JTU	48	2.4	15.0
pH	pH	9.36	6.68	8.2
Total Disslv.Solids	mg/l	642	659	1002.
Suspended Solids	mg/l	98.57	2.43	27.05
Alkalinity	mg/l $CaCO_3$	255	104	172.
Boron	mg/l B	0.90	0.92	1.34
Carbon Dioxide	mg/l CO_2	0	51.34	1.99
Chlorine Demand/hr	mg/l Cl	2.26	2.50	0.71
Chlorine Residual	mg/l Cl	0.4	1.10	0
Total Hardness	mg/l $CaCO_3$	63.6	61.8	132
MBAS	mg/l LAS	0.114	0.100	0.063
Ammonia Nitrogen	mg/l N	0.035	0.024	0.54
Organic Nitrogen	mg/l N	10.7	1.6	2.26
Nitrite Nitrogen	mg/l N	0.015	0.005	0.021
Nitrate Nitrogen	mg/l N	0.13	0.14	0.34
BOD	mg/l O	29.2	1.1	2.0
Total COD	mg/l O	163	30.57	46.08
Dissolved Oxygen	mg/l O	10.7	8.8	8.8
Ortho Phosphate	mg/l PO_4	24.74	0.23	0.23
Total Phosphate	mg/l PO_4	29.53	0.22	0.46
Potassium	mg/l K	19.0	18.57	21
Sodium	mg/l Na	200	199	280
Sodium Equiv. Ratio	% Na	83.17	83.40	79.7

Table 15 (Continued)
AVERAGE WATER QUALITY CHARACTERISTICS
FOR DECEMBER, JANUARY, FEBRUARY, 1971 AND 1972

CONSTITUENT	Units	Tertiary Plant Influent	Tertiary Plant Effluent	Apollo Lakes
Temperature	°F	41.6	43.5	40.6
Turbidity	JTU	29.0	1.15	18.53
pH	pH	9.50	6.36	8.37
Total Disslv.Solids	mg/l	554	564	861
Suspended Solids	mg/l	84	0.5	34.37
Alkalinity	mg/l $CaCO_3$	233	66	158
Boron	mg/l B	0.91	0.88	1.25
Carbon Dioxide	mg/l CO_2	0	50.6	0.934
Chlorine Demand/hr	mg/l Cl	2.95	0	0.89
Chlorine Residual	mg/l Cl	-	-	0
Total Hardness	mg/l $CaCO_3$	65.63	64.75	117
MBAS	mg/l LAS	0.1	0.1	0.12
Ammonia Nitrogen	mg/l N	0.46	0.495	0.618
Organic Nitrogen	mg/l N	10.48	3.47	1.74
Nitrite Nitrogen	mg/l N	0.035	0.002	0.002
Nitrate Nitrogen	mg/l N	0.87	1.02	1.244
BOD	mg/l O	23.07	1.51	1.355
Total COD	mg/l O	166.4	32.25	40.10
Dissolved Oxygen	mg/l O	12.6	12.67	10.62
Ortho Phosphate	mg/l PO_4	25.58	0.085	0.27
Total Phosphate	mg/l PO_4	27.49	0.156	0.407
Potassium	mg/l K	16.25	15.125	18.4
Sodium	mg/l Na	169	160	218
Sodium Equiv. Ratio	% Na	80.8	80.46	79.5

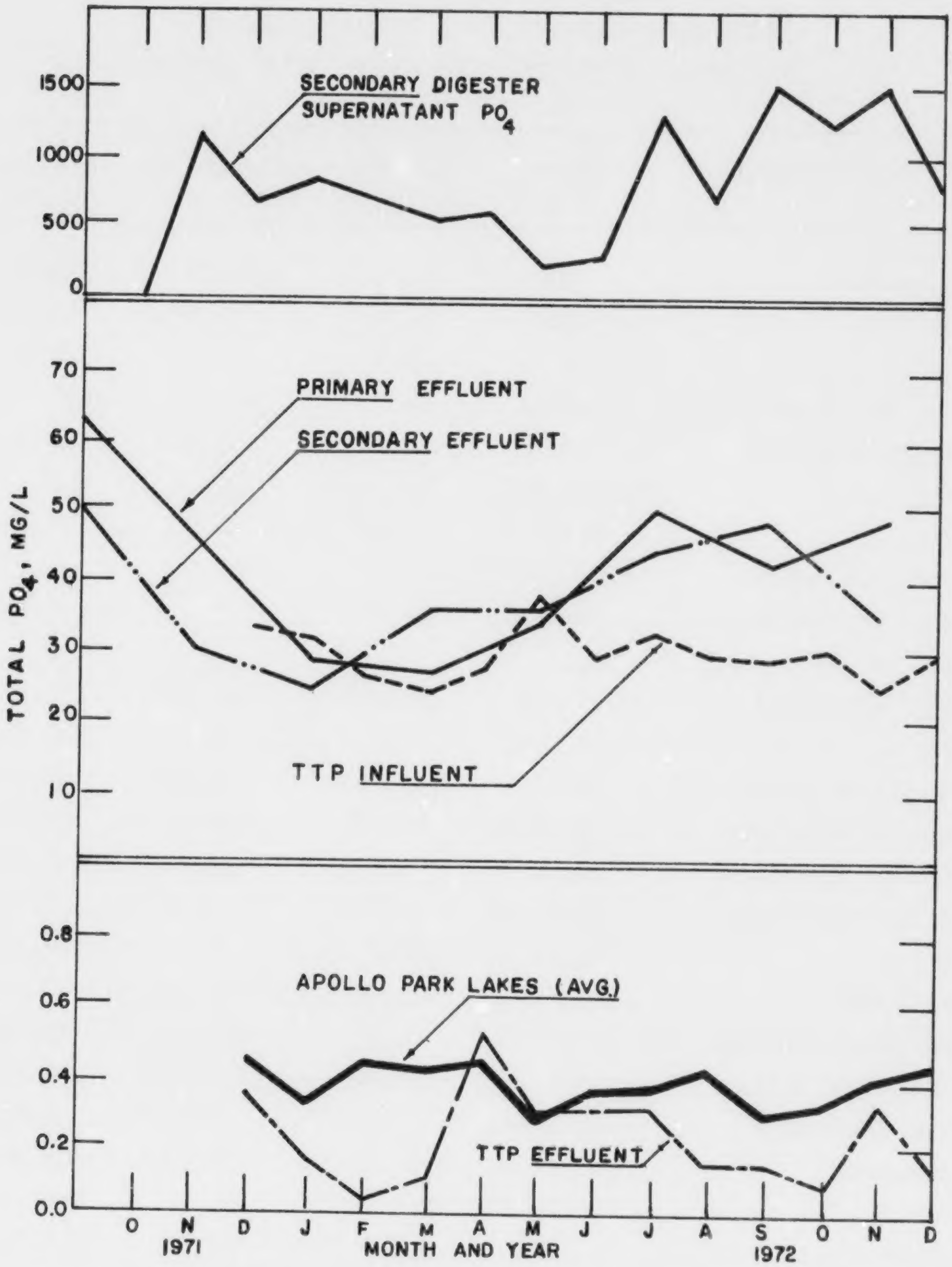


Figure 32 AVERAGE MONTHLY PHOSPHATE CONCENTRATIONS

Influent pH and alkalinity are shown in Figure 33. The average monthly pH fluctuated during the study period from lows of 8.5 and 8.6 in November, 1971 and April, 1972, respectively, to high values of 9.3 and 9.7 in February and June, 1972, respectively. Alkalinity fluctuated from a low of 224 mg/l (as $CaCO_3$) in February, to a high of 265 mg/l in July.

The pH of the pond rose to a high level in early spring corresponding to increases in temperature, suspended solids, and algae. This seemed to reflect the increase in CO_2 utilization by the algae as they become increasingly active. Removal of CO_2 from the water would cause the pH to rise. A decrease in alkalinity accompanied the change in the pH. Alkalinity was always sufficiently high to ensure proper flocculation pH control in the TTP. Since 1 mg/l of alum removes 0.5 mg/l of alkalinity, levels of over 200 were adequate for buffering pH. For comparison, the effluent levels of alkalinity and pH are also shown in Figure 33.

Average monthly flows are plotted in Figure 34. The amount of flow treated depended primarily upon the demand of the recreational lakes. This demand was variable due to different seasonal evaporation and irrigation rates. Average monthly flows ranged from a low of 910 m^3/day (0.24 mgd) during February, to a high of 2650 m^3/day (0.727 mgd) during September. The annual average influent flow was 1760 m^3/day (0.463 mgd). The difference between the average monthly influent and effluent flows of 430 m^3/day (0.11 mgd) is due to the alum sludge flow and the water needed for filter backwash.

The above averages and other feed pond characteristics determined during the study period are listed in Table 15, together with effluent values. For a comparison, the

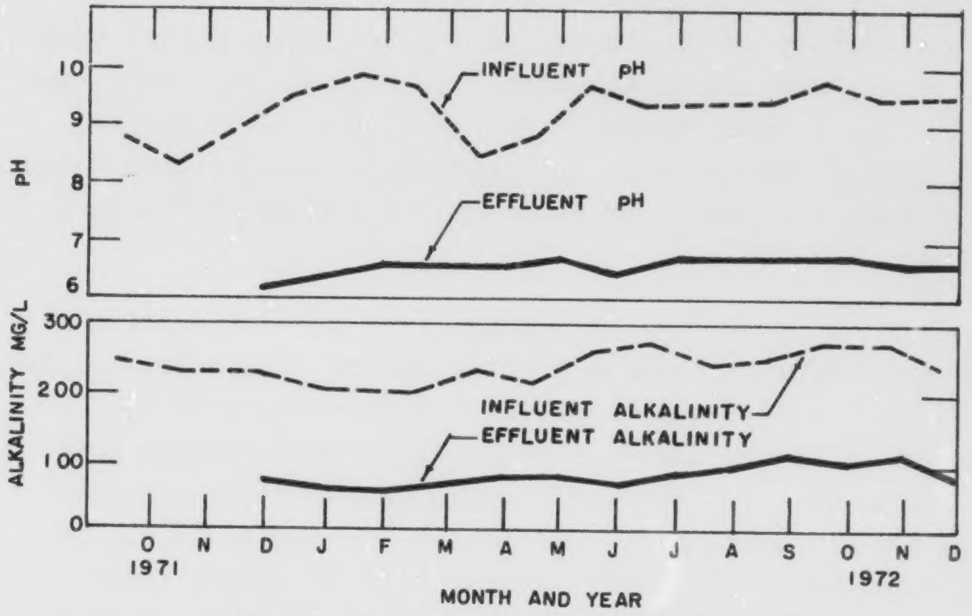


Figure 33 TTP INFLUENT AND EFFLUENT pH AND ALKALINITY LEVELS

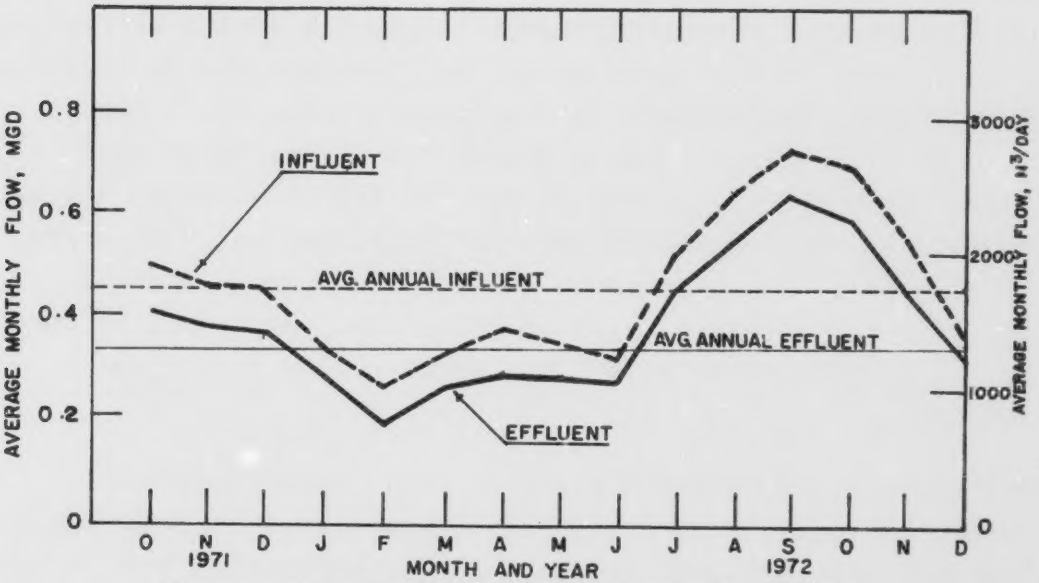


Figure 34 TERTIARY TREATMENT PLANT FLOWS

corresponding averages for the Apollo Lakes are also shown. Because these characteristics are affected by weather conditions, this table is compiled on a seasonal basis. The values are averages and should be taken as approximate generalizations. Also for comparison, the pilot plant feed pond characteristics are also listed in Table 16 with the average tertiary plant feed pond characteristics as computed over the study period. The pilot plant feed pond characteristics are those upon which the tertiary plant design was based. The major differences between the two studies are the pH, turbidity, and ammonia levels. Although not shown in the table, the algal populations were quite different. Green algae were predominant during the pilot study, while the blue-greens were predominant during a large portion of the optimization study. This condition resulted in many operational problems not encountered in the pilot study.

Effluent Characteristics

The final effluent turbidity (JTU) and PO_4 concentrations are shown in Table 15 and Figure 32. These are the monthly averages for the period of study. PO_4 concentration ranged from a minimum of 0.10 mg/l during February, to a maximum of 0.55 during October, 1971. The average concentration during the study was 0.28 mg/l. Turbidity, expressed in JTU, ranged from a low of 0.8 during February, to a high of 3.0 during June. The average turbidity during the study was 1.5 JTU.

Removal of phosphates was a primary goal of the tertiary plant design, and the average phosphate removal was about 99%. Other nutrient substances of interest are organic nitrogen, nitrates, nitrites, and ammonia nitrogen. The treatment process removed an average of 86.2% of organic nitrogen. Nitrates, nitrites, and ammonia nitrogen were unaffected by the treatment process.

Table 16
COMPARISON OF AVERAGE FEED POND CHARACTERISTICS FOR PILOT PLANT AND TERTIARY PLANT

Constituent	Unit	Pilot Plant Feed Pond	Tertiary Plant Feed Pond
pH	pH units	8.3	9.2
Turbidity	JTU	90	45
Total Alkalinity	mg/l, $CaCO_3$	260	245
Hardness	mg/l, $CaCO_3$	80	63
Suspended Solids	mg/l	75	99
Total Dissolved Solids	mg/l	575	645
COD	mg/l	250	184
BOD	mg/l	38	32
Dissolved Oxygen	mg/l	0.1-40	3.6-19.6
Ammonia Nitrogen	mg/l, N	0.1-20	0-2.0
Organic Nitrogen	mg/l, N	7-20	8.1-20.7
Nitrate Nitrogen	mg/l, N	1-4	0-1.9
Nitrite Nitrogen	mg/l, N	0.1-12	.01- .6
MBAS	mg/l, ABS	3	0.11
Phosphates	mg/l, P	40	31

Process Optimization

Data was collected to determine the flocculation pH that would give the least cost of treatment at the design flow of 1900 m^3/day (0.5 mgd). The desired pH is obviously the maximum one that will still maintain acceptable effluent conditions, or in other words the least amount of alum dosage required. This is not necessarily the pH which will result in the greatest efficiency with respect to effluent production on a flow basis. The following efficiency formula is used to compute production efficiency:

$$\% \text{ efficiency} = \frac{\text{Effluent Flow}}{\text{Influent Flow}} \times 100$$

The formula does not consider the cost of alum dosage and depends upon how concentrated the alum sludge is and how often the filter requires backwashing. This study did not address itself to the optimization of effluent production specifically.

During periods of design flow, the flocculation pH was varied over a range to determine the effect on effluent turbidity and PO_4. The amount of representative data collected in this manner was minimal due to various operational problems encountered during the period of study. The major problems were:

1. Due to variable demands for product water at the recreational lakes and blue-greem algae predominance, design flow was adequately maintained only during brief periods in November and December of 1972.
2. Physical modifications to the process were made in August, 1972. One of the modifications was a baffle installed between the flocculation chamber and the sedimentation tank. Also, the sludge collector flight speed was reduced from 91.4 cm/min (36 in/min) to 48.3 cm/min (19 in/min). Both of these modifications increased the operational stability of the TTP.
3. Experimentation with the flocculator paddle speed during September and October of 1972 introduced another variable into the process, making comparison with other operational data meaningless with respect to determining flocculation pH values.

The data collected in November and December, 1972 are shown in Figures 35, 36, 37, 38, and 39. Figure 35 shows alum dosage and effluent PO_4 as functions of the flocculation pH. For the influent conditions during this specific period, it appears that a pH of about 6.4 resulted in maximum PO_4

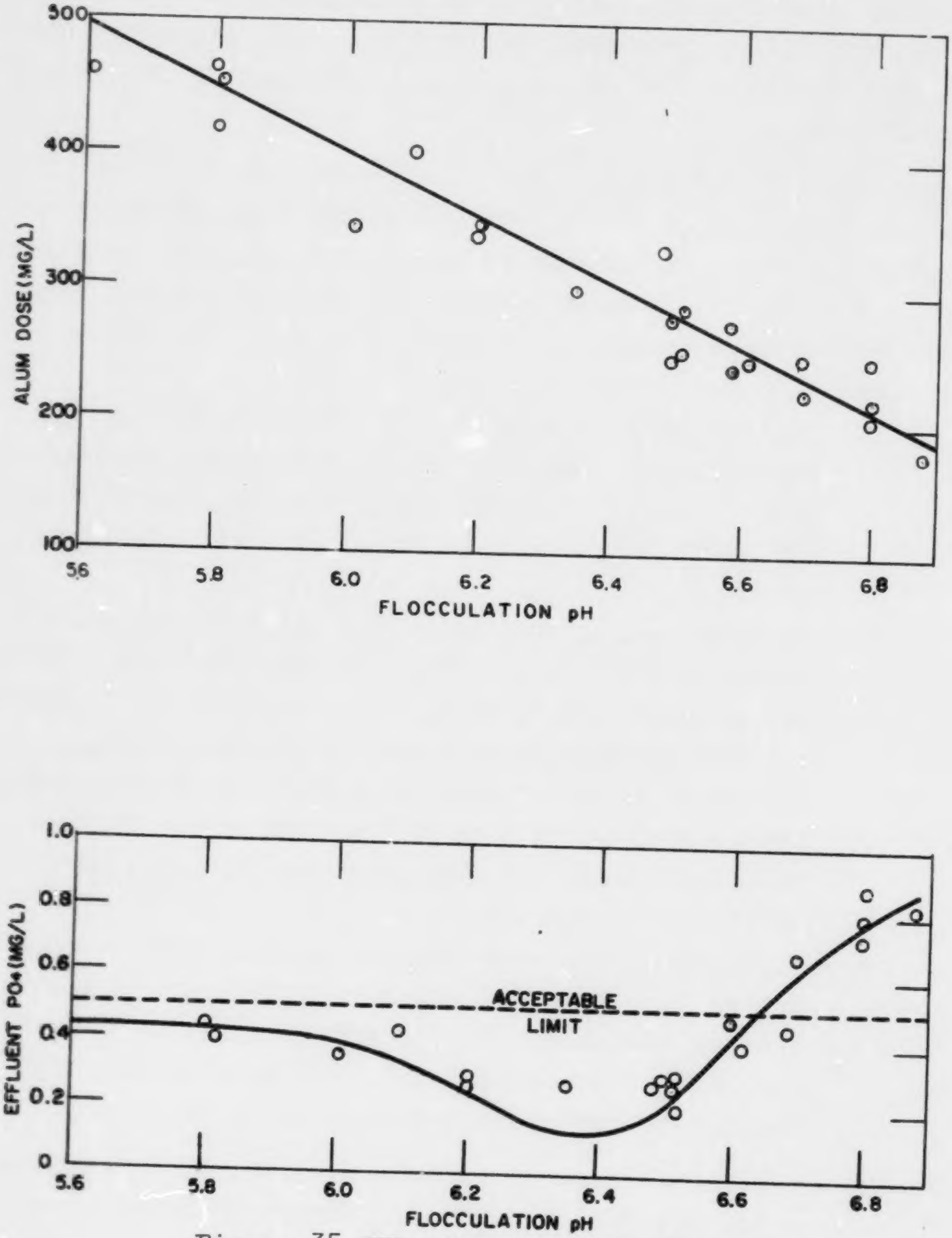


Figure 35 TTP ALUM DOSE AND EFFLUENT PHOSPHATE vs. FLOCCULATION pH

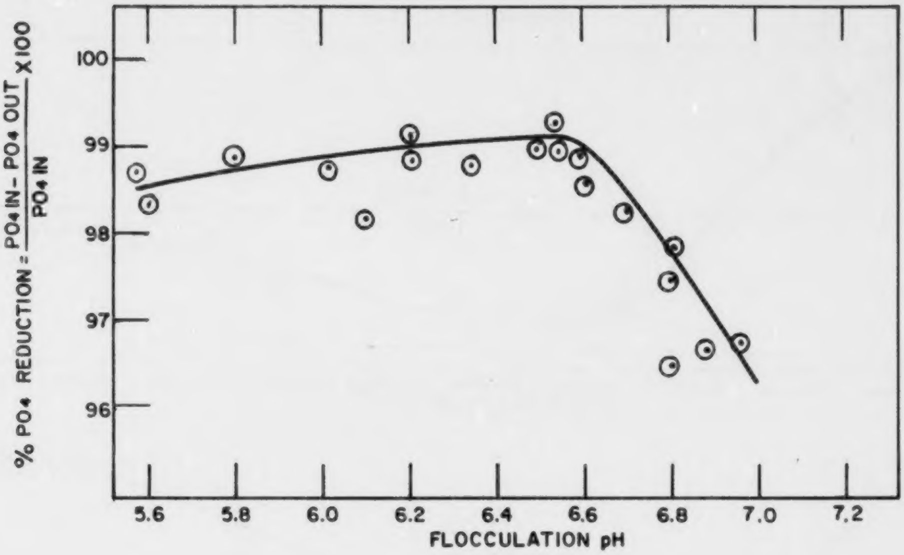


Figure 36
TTP PHOSPHATE REDUCTION vs. FLOCCULATION pH

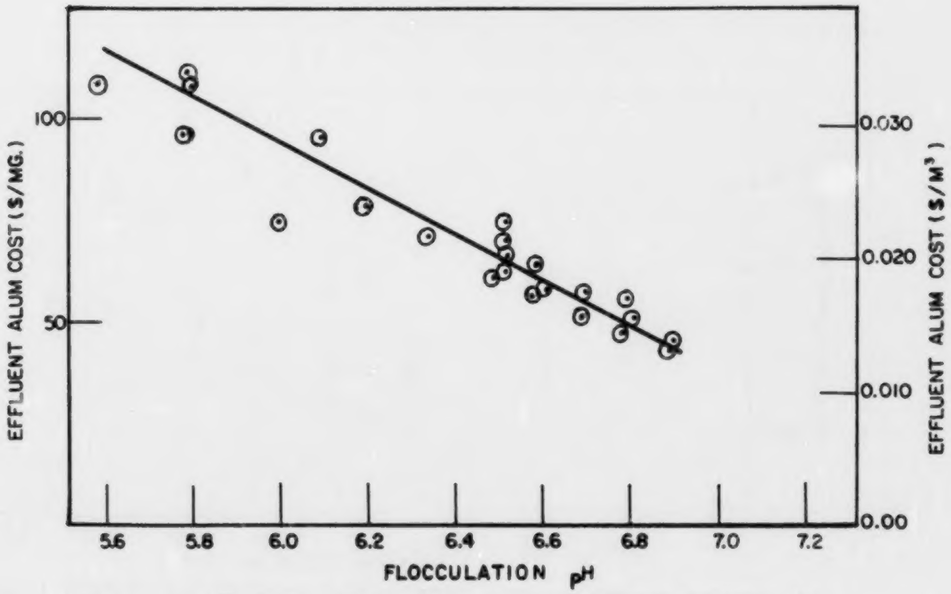


Figure 37 TTP ALUM COST vs. FLOCCULATION pH

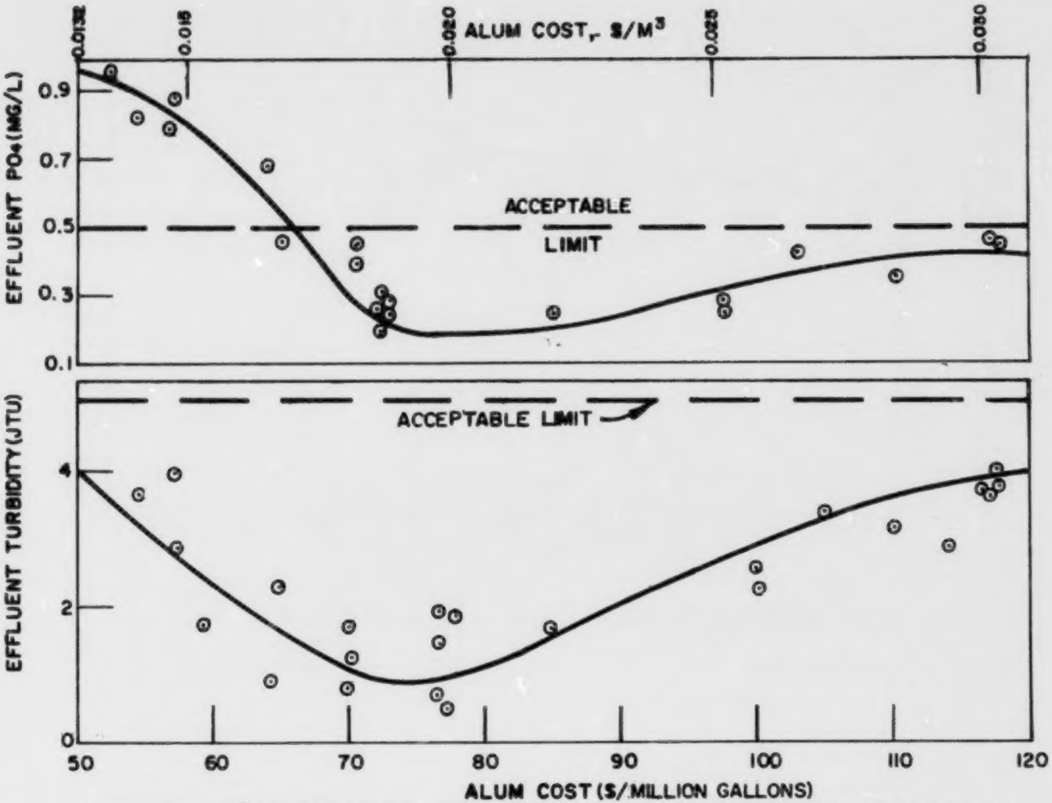


Figure 38 TERTIARY TREATMENT PLANT EFFLUENT PHOSPHATE AND TURBIDITY vs. ALUM COST

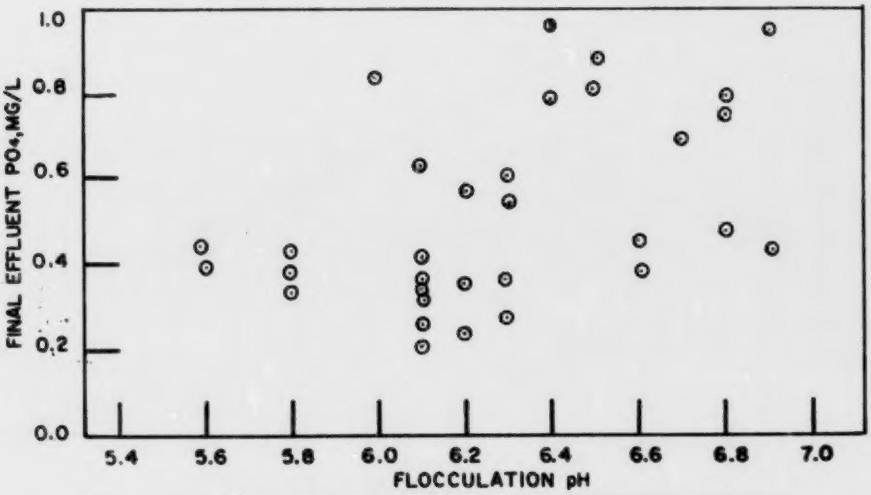


Figure 39 FINAL EFFLUENT PHOSPHATE LEVELS vs. FLOCCULATION pH AT DESIGN FLOW

reduction.

While a pH of 6.6 would have resulted in about 17% less alum cost, the instability of the process increased sharply for pH values above 6.5. This is illustrated by the slope of the curve in Figure 36. Also, the increase of solids going to the filter at a pH of 6.6 would require more frequent backwashing. This would result in a decrease in the effluent water produced for the recreational lakes. There was not enough data for these specific conditions to determine what the optimum pH would be on a simple cost per effluent volume basis, so the effect of increased backwashing due to increased turbidity and PO_4 in the sedimentation tank effluent was not determined.

To obtain a pH of 6.4, an alum dosage of about 300 mg/l was required, and the alum cost, at a flow of 1900 m^3/day (0.5 mgd) equaled $22 per 1000 m^3 (or $84 per million gallons) produced. The overall economics of plant operation are discussed separately later in this section.

It should be pointed out that these data are only applicable to the period in which they were collected.

Discussion of Data

Factors Affecting the TTP Process Operation - The operation of the TTP is a function of many factors which can vary over time. These factors include the natural changes in the influent characteristics mentioned previously, as well as the physical operational variables controlled by the operator. These variable factors can cause changes in operation over both long and short time periods. Seasonal changes occur gradually, for example, compared to suspended solids fluctuations resulting from high winds. In short, it is impossible to operate the TTP at a single pH value efficiently over an extended period of time. The data presented in Figures 35 through 38 were applicable only to the period of operation at that specific time period. Even then, the data does not apply for variations in flow. Detention time fluctuations change the operational characteristics of the TTP significantly.

When one analyzes the daily operational data over a reasonable period of time, it is apparent that ranges of operational variables apply, rather than single values. For example, flocculation pH can, and does, range from 5.9 to 6.7 depending upon the variable operating conditions. Even when the data for only one flow is studied, it is apparent that operational ranges apply rather than single values. This point is clearly illustrated by the data plotted in Figure 39 where operating characteristics for approximately 5 months are presented. This data represents conditions at design flow.

Efficiency can be maximized by only dosing the influent with enough alum to maintain both the effluent standards and operational stability. Excess alum dosage does not result in any benefit in operation and, therefore, is not desirable.

The ranges referred to above are listed in Table 2 , with the original design criteria that the TTP design was based upon. The comparison between the parameters is discussed in the next section.

Comparison of Operating and Design Parameters - Upon review of the data shown in Table 2 , several major differences between the design and operational parameters are apparent. These differences are as follows:

1. Influent flow to the full-scale plant depends primarily upon the demand for product water at Apollo County Park and the recreational lakes. Higher flows are required in the summer than in the winter, due to

the high evaporation rate in the lakes and irrigation demands.

2. The pH and alum dosage in the flocculation chamber depend upon the influent conditions, as described previously. The paddle tip speed, however, had to be kept below about 24.4 cm/sec (0.8 fps) to maintain good floc characteristics. It should also be pointed out that in order to improve the stability of the coagulation-sedimentation process, the flocculation chamber and sedimentation tank had to be separated by a baffle. A wooden baffle was installed in August 1972, and the operational stability of the process was, in fact, increased.
3. Flight speed in the sedimentation tank was reduced from 91.44 cm/sec (36 in/min) to 48.3 cm/min (19 in/min) to increase the sludge concentration. The concentration (0.1-0.3%) still is much less than the expected design value of 3.0%. This results in increased sludge flows, causing plant efficiency to also be significantly less than the design value. The design values for sludge flow, however, are misleading since the plant could never operate at the listed values. This is because a 3% sludge flowing at 5% of plant flow would remove approximately 2-3 times the total maximum solids which could theoretically be removed from the influent. In other words, if the sludge could be concentrated in the sedimentation tank to a value of 3%, the resulting sludge flow would be closer to 2% of plant flow, rather than the design value of 5%.
4. The difficulty in concentrating alum sludges by gravity sedimentation is the major factor contributing to reduced flow production efficiencies.

Concentration is possibly hampered by the fact that the sludge flights return approximately 61 cm (2.0 ft) above the scraping flights in the tank. It is felt that these flights should be returned above the water surface in the sedimentation tank to avoid any disruption of sludge consolidation.

5. Although the sludge flight design outlined above could contribute to less than maximum sludge concentration, the design value of 3% will probably never be realized with the present process operation. Possibly polymers or an additional dewatering process should be evaluated for improving sludge concentration. It is felt that some additional process modification is necessary if the plant is expected to operate at design efficiencies, with respect to flow.

Effluent Parameters

The desired PO_4 and turbidity removals were usually easily achieved during full scale TTP operation. Blue-green algae predominance, however, did result in increased alum dosage and decreased flows and efficiencies. The difficulty in operation of the plant is more of an efficiency problem based upon flow rather than effluent quality. This is due to the inability of the process to concentrate the alum sludge, as described below.

Conclusions

Two major factors limited flow production efficiency. First, blue-green algae were frequently the predominate algae type in the plant influent. Whenever this occured, very poor settling resulted in the sedimentation chamber, the algae passed into the filter, and more frequent backwashings were needed. As the frequency of backwashing increased, flow production decreased. The types of algae in the influent were a result of seasonal and other environmental conditions in the oxidation ponds.

The second factor that limited flow production efficiency was the flocculent nature of the alum sludge formed in the sedimentation tank. This was related to the type of algae occurring in the influent, with blue-greens again having an adverse effect, and to design deficiencies in the sedimentation tank. Recommendations for improving the design of the sedimentation tank are given earlier.

When green algae predominated it was possible to treat a flow of 2840 m^3/day (0.75 mgd) adequately. This value is approximately 36% greater than the design flow.

Optimum values of flocculation pH, based upon operational stability, PO_4 and turbidity reduction and efficiency, were determined for the full scale TTP. These values, however, only applied for "constant" influent and operational characteristics (short intervals of operation). A range of operational parameters, including flocculation pH, rather than single values, applied to the actual operation of the TTP for the variable influent and operational parameters normally encountered over the period of study.

Recommendations

Effort should be directed to minimizing the predominance of blue-green algae populations. This will increase the percent efficiency as explained above.

The feasibility of adding a process, or improving the present process to increase the alum sludge concentrations should be evaluated. Possibilities could include polymer addition, modification of the sludge flight operation and a sludge thickening or dewatering process.

ALUM SLUDGE STUDY

Purpose

The purpose of the Alum Sludge Study was three-fold: the first was to determine if alum sludge from the tertiary process adversely affects the anaerobic digestion process; the second was to find the amount of phosphate that is recycled to the tertiary plant influent by the digester supernatant or primary effluent pathways; and the third was to characterize the properties of alum sludge and the co-settled mixed sludge (the combined alum and raw sludges) to determine if either sludge exhibited any undesirable characteristics.

Tertiary Treatment

The tertiary plant was designed to dose alum at 300 mg/l and produce a sludge concentration of about 3%. This dose rate of alum is within operational limits, but the maximum sludge concentration that has been obtained (see Figure 40) is 0.75% with a typical value of 0.2%. This ten-fold dilution in sludge concentration made it impossible to convey the alum sludge directly to the anaerobic digesters without causing the digestion process to fail because of hydraulic overloading. To circumvent digester failure the alum sludge was conveyed to the primary plant wet well and cosettled with the raw sludge in the primary sedimentation tanks.

The major function of the tertiary process is to reduce phosphates. Since the phosphates that are removed are recycled back to the primary and secondary processes, a phosphate mass balance was done to determine if any long-term phosphate buildup problems exist. To perform this phosphate mass balance the characteristics of the alum sludge, tertiary plant feed, and digester supernatant had to be known together with digested sludge phosphate levels.

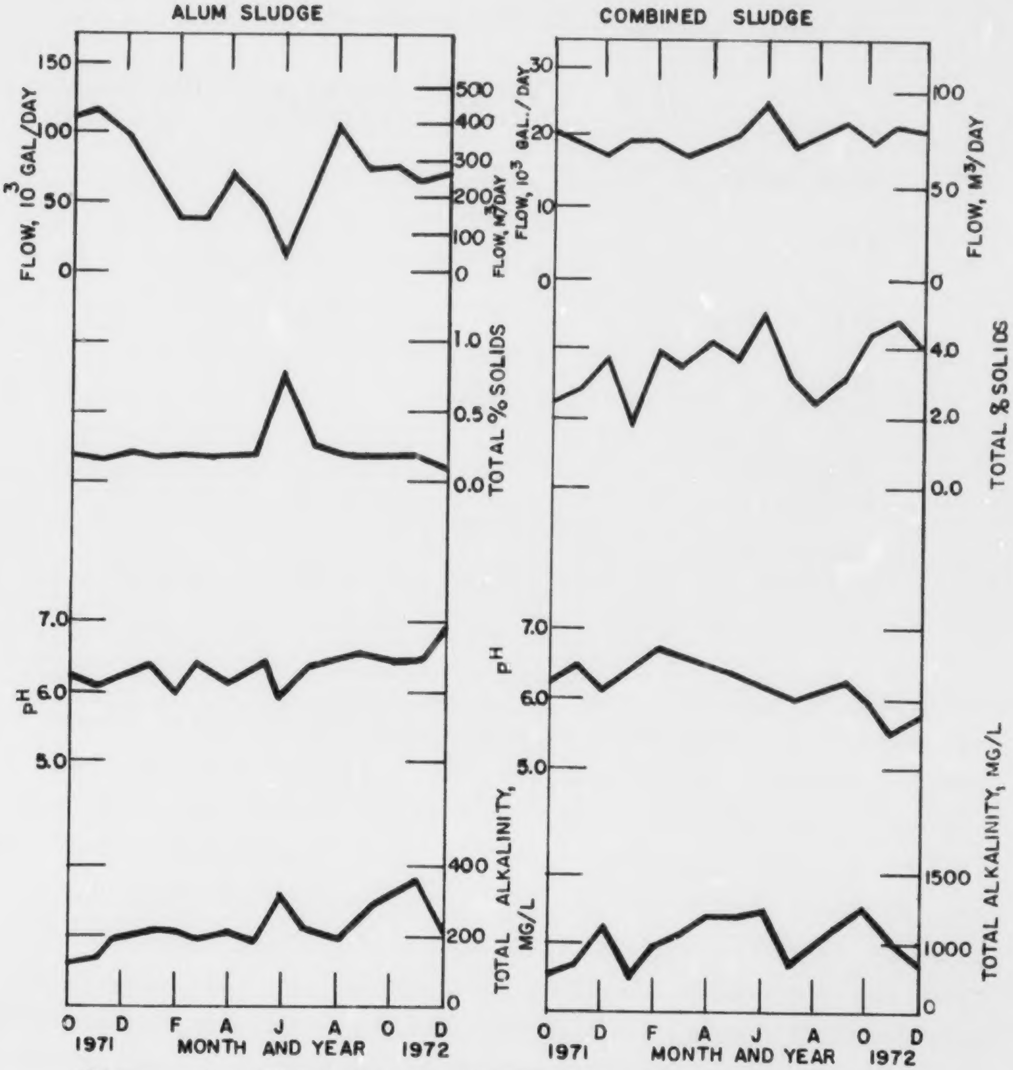


Figure 40 ALUM AND COMBINED SLUDGE CHARACTERISTICS

Data collection was started in October, 1971 and was continued until December, 1972. The qualities measured are shown on Table 17 and include sludge and digester characteristics. The condition of the anaerobic digestion process was monitored by measuring gas production, volatile acid, and alkalinity levels. The alum and combined sludges were examined for pH, total solids and alkalinity, and records were kept on the daily flows of each sludge.

Table 17 ALUM SLUDGE STUDY PARAMETERS

Parameter	Alum Sludge	Mixed Sludge	Primary Digester	Secondary Digester
Flow Rate	X	X		
pH	X	X	X	X
Total Alkalinity	X	X	X	X
Total Solids	X	X		
Volatile Acids			X	X
Total Gas Prod.			X	X

Digester Operation

The anaerobic digesters at Lancaster are circular fixed covered units. Each digester has a liquid capacity of 2320 m^3 (612,000 gallons). The first digestion stage occurs in the primary digester which is both heated and mixed. The second digestion stage is fed by the overflow from the primary digester and it acts as a thickener. Supernatant from the secondary digester is recycled to the oxidation ponds and the subnatant sludge is air dried in shallow beds. The energy required to heat the digesters is normally obtained by burning digester gas. Mixing is achieved by compressing digester gas and injecting it into the primary digester draft tube.

Originally the alum sludge was to have been fed directly to the primary digester. However, as stated earlier, the thinness of the sludge made this impractical, so it was added to the raw sewage as shown in Figure 9 and 10. The combined sludge solids content averaged a little less than

4% which is within the range of most primary sludges. The detention time in the primary digester at an average combined sludge flow of 79.2 m^3/day (21,000 gallons per day) is nearly 30 days. If alum sludge from the tertiary plant at 188 m^3/day (50,000 gpd) had been used in addition to primary sludge as digester feed, the detention time would be less than 9 days. Detention times of such short duration would make consistent digester operation impossible.

The primary digester was held within the 32-35°C (90-95°F) temperature range by recirculating hot water through the combined draft tube heat exchanger. The secondary digester or thickener had sludge withdrawn from it when the supernatant contained more than 0.75 - 1% solids. The supernatant was mixed with the primary effluent and this combination made up the feed for the oxidation ponds. The supernatant is one major source of recycled phosphate to the oxidation ponds.

Digester Performance

The first instance of digester change occurred early in 1972 when the alkalinity of the primary digester dropped from a high value of 3000 mg/l to a lower value of 2000 mg/l. This change was preceeded by a change in the alkalinity level of the combined sludge. The alum sludge, however, was constant during this period, so the change in digester alkalinity was probably due to a change in the alkalinity level of the primary sludge. The volatile acid level in the primary digester rose slightly above its normal value, perhaps due to the change in buffering capacity of the digester.

In early June a true digester upset was observed and it was found this upset was due to an operational error. The digesters were hydraulically overloaded when the "thick" sludge was diluted with wash water in an attempt to get the raw sludge pump to pump more sludge. The wash water was on for several days and this added flow was sufficient to wash out some of the methane-forming bacteria causing the digester's process to become unbalanced. The upset is shown graphically on Figures 41 and 42 as is another upset in mid-September.

The values shown in these figures are monthly averages. However, the volatile acids reached measured peak values of 2500 and 2800 mg/l in the primary and secondary digesters respectively. Alkalinity reached a peak of 5200 mg/l in the secondary digester, and the gas production for the two digesters dropped to a measured weekly low rate of 480 m^3/d (17,000 ft^3/day).

The September upset was of short duration because the wash water flow was stopped before too much dilution had occurred. The combined sludge feed was shifted to the secondary digester which allowed the primary digester to recover quickly. This upset was again tied to the inability of the centrifugal pump to convey the sludge solids to the digester.

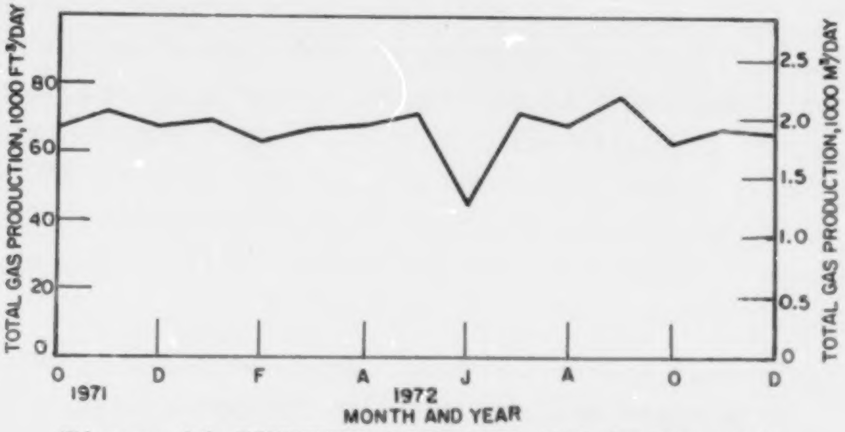
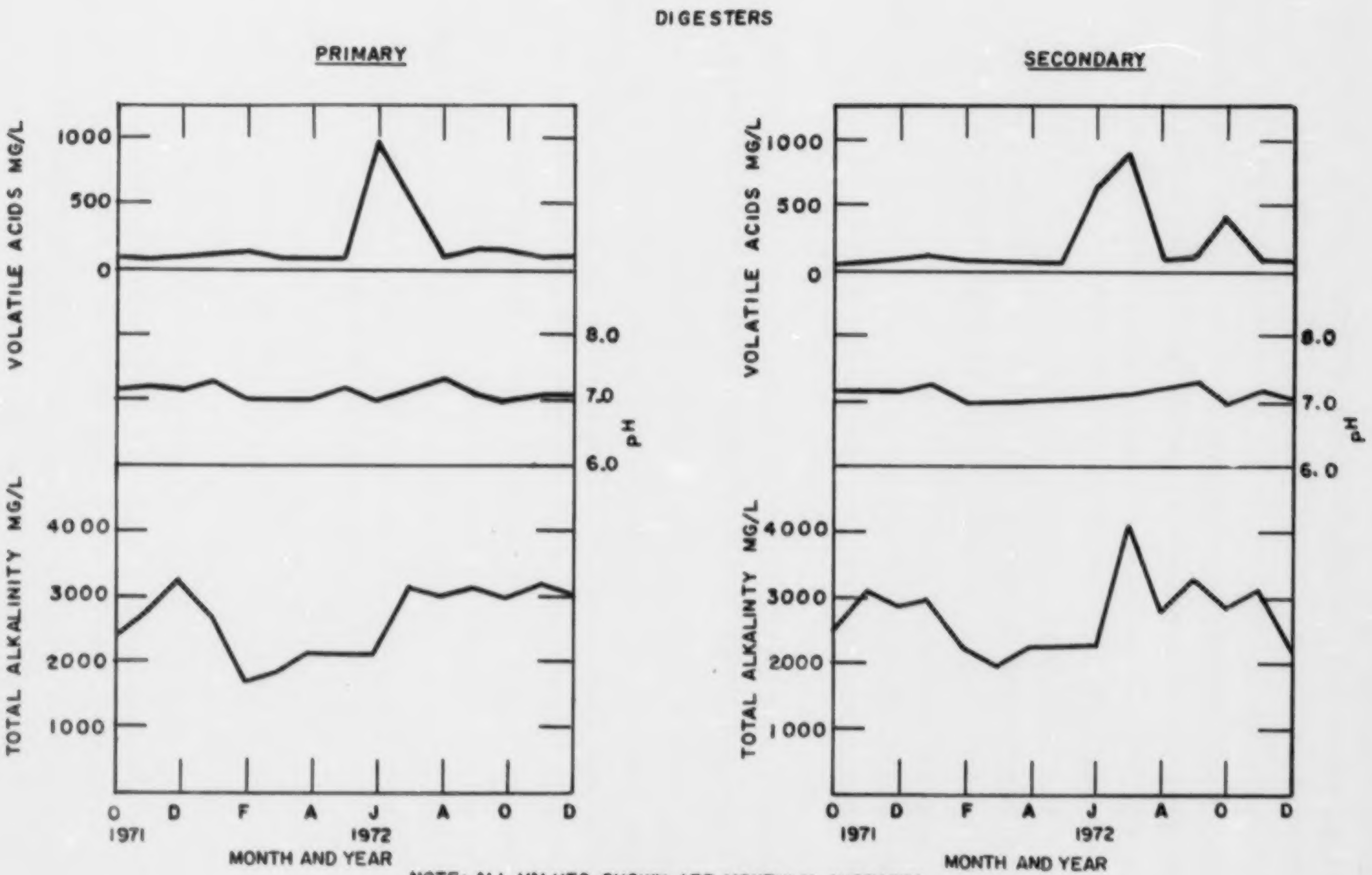


Figure 41 COMBINED DIGESTER GAS PRODUCTION



NOTE: ALL VALUES SHOWN ARE MONTHLY AVERAGES

Figure 42 DIGESTER CHARACTERISTICS

Phosphate Mass Balance

A mass balance for phosphate was conducted on the combined secondary-tertiary treatment system. The purpose of the mass balance was to determine if excessive phosphate concentrations could accumulate in the secondary treatment system. A flowsheet for the phosphate pathways is presented as Figure 43. The flowsheet indicates that the tertiary plant removed about 99% of the phosphate in the influent to the plant. The phosphate removal in the secondary treatment plant primary tank is about 25% which is greater than the 10-20% removal found at most other treatment plants. However, higher levels of phosphate are in the influent to the primary plant because of the alum sludge. About 70% of the phosphate in the influent to the anaerobic digesters is removed when sludge is withdrawn from the digesters. The two sources of phosphate addition to the oxidation ponds are due to primary plant effluent and digester supernatant.

The phosphate levels of the primary effluent and pond effluent were determined on several occasions and were used to complete the mass balance. Evaporation rates for the Apollo Park Lakes were obtained for the period of the study, and used in conjunction with the monthly oxidation pond surface areas to determine the quantity of effluent lost by evaporation. The average quantity of pond water lost by evaporation was substracted together with tertiary plant influent flow from the metered raw sewage flow.

Figures 32 and 44 show a comparative summary of the phosphate measurements, both in terms of kg/day mass flow and in concentration. For contrast, the phosphate concentrations in the Apollo Park Lakes are also shown. The sampling locations for these phosphate measurements are:

1. Primary effluent: this is the effluent from the primary sedimentation tank. It does not include digester supernatant.

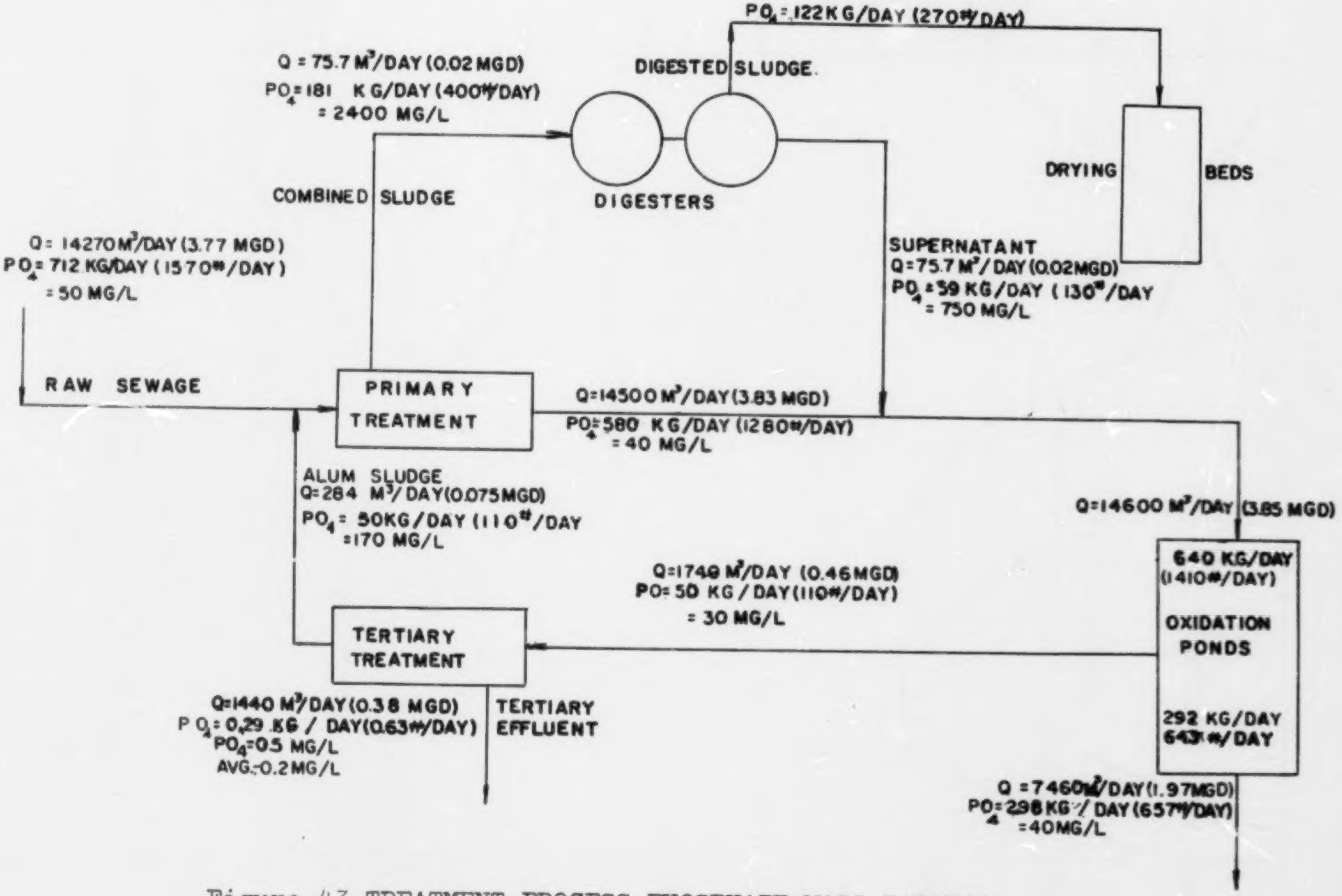

PO_4 = 122 KG/DAY (270#/DAY)
DIGESTED SLUDGE.
Q = 75.7 M^3/DAY (0.02 MGD)
PO_4 = 181 KG/DAY (400#/DAY)
= 2400 MG/L
DIGESTERS
DRYING BEDS
COMBINED SLUDGE
Q = 14270 M^3/DAY (3.77 MGD)
PO_4 = 712 KG/DAY (1570#/DAY)
= 50 MG/L
RAW SEWAGE
SUPERNATANT
Q = 75.7 M^3/DAY (0.02 MGD)
PO_4 = 59 KG/DAY (130#/DAY
= 750 MG/L
PRIMARY TREATMENT
Q = 14500 M^3/DAY (3.83 MGD)
PO_4 = 580 KG/DAY (1280#/DAY)
= 40 MG/L
ALUM SLUDGE
Q = 284 M^3/DAY (0.075 MGD)
PO_4 = 50 KG/DAY (110#/DAY
= 170 MG/L
Q = 14600 M^3/DAY (3.85 MGD)
640 KG/DAY
(1410#/DAY)
OXIDATION PONDS
292 KG/DAY
643#/DAY
Q = 1749 M^3/DAY (0.46 MGD)
PO = 50 KG/DAY (110#/DAY)
= 30 MG/L
TERTIARY TREATMENT
Q = 1440 M^3/DAY (0.38 MGD)
PO_4 = 0.29 KG/DAY (0.63#/DAY)
PO_4 = 0.5 MG/L
AVG. -0.2 MG/L
TERTIARY EFFLUENT
Q = 7460 M^3/DAY (1.97 MGD)
PO_4 = 298 KG/DAY (657#/DAY)
= 40 MG/L

Figure 43 TREATMENT PROCESS PHOSPHATE MASS BALANCE

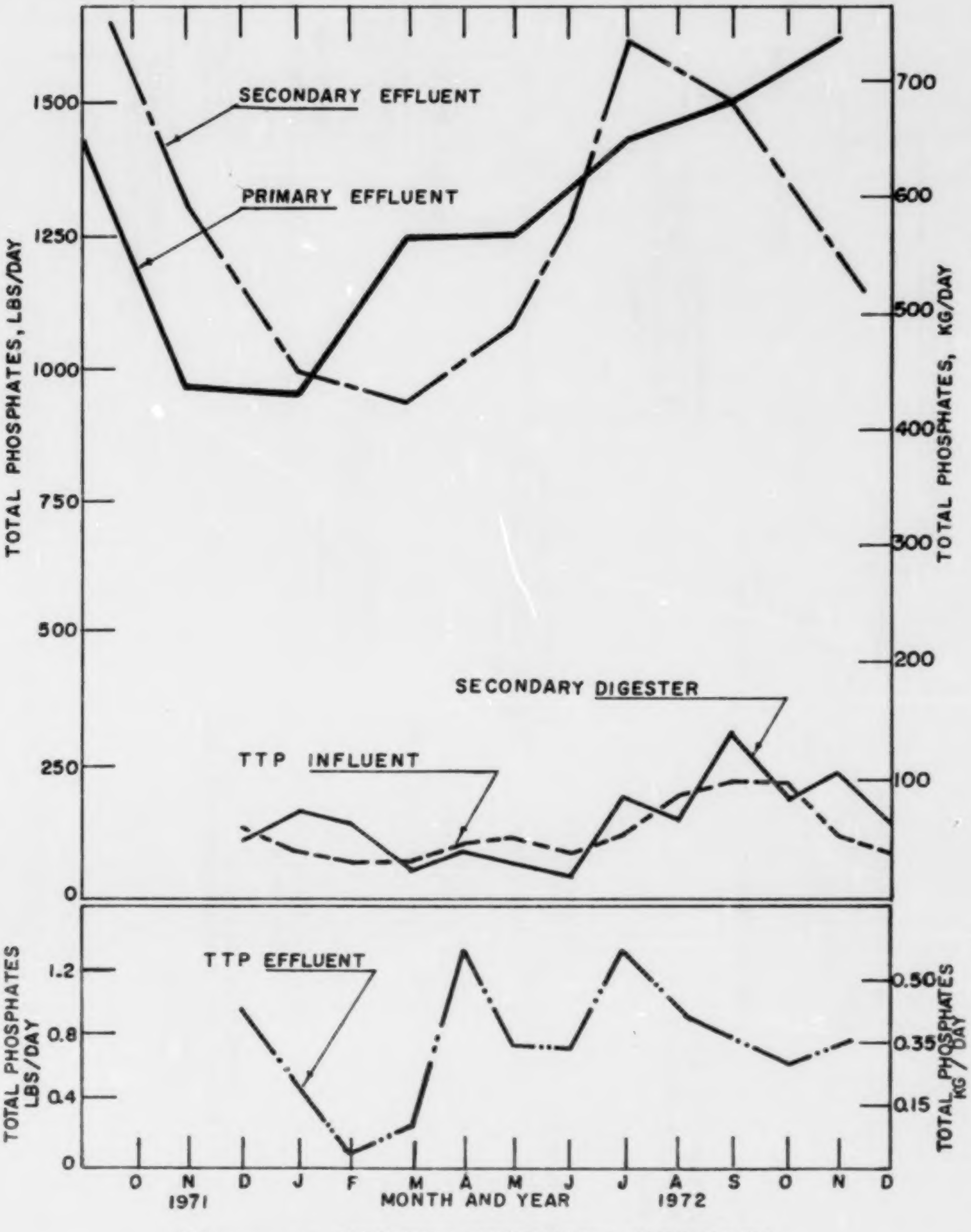


Figure 44 MONTHLY PHOSPHATE MASS FLOW

2. Secondary effluent: this is the excess effluent from the oxidation ponds which flows toward the Rosamond Dry Lake storage pond.
3. TTP influent: this is the water taken from the oxidation pond No. 1 as influent to the tertiary plant.
4. TTP effluent: these samples were taken from a point downstream of the chlorine contact chamber.
5. Secondary digester supernatant: these samples were taken from the secondary sludge digester supernatant draw-off line. The supernatant is discharged into the oxidation ponds.

According to the phosphate balance calculations, the phosphate buildup in the ponds averaged about 290 kg/day (640 lbs/day) (see Figure 43), but this increase in phosphate level is not noted in the TTP influent even after 3 years of operation. It is surmised that the phosphate buildup in the ponds is held in the sludge that accumulates within the oxidation ponds.

Sludge Characteristics

The alum sludge as previously described is very thin, averaging about 0.2% total solids. It also has a low volatile matter content of about 50% and the buffering capacity of the sludge is low as indicated by a total alkalinity of 200 mg/l. The nutrient level of the sludge is low as indicated by a biochemical oxygen demand (BOD) of 70 mg/l. As expected, the sludge contains high levels of phosphate averaging about 170 mg/l.

The combined alum and raw sludges cosettled in the primary sedimentation tank are characterized by total solids content of around 4% which is within the 3-7% range of primary sludge. The combined sludge has reasonable buffering capacity as indicated by an alkalinity of greater than 1000 mg/l.

Conclusions

The alum sludge did not adversely affect the operation of the digesters even though the alum sludge had to be cosettled in the primary sedimentation tank. Although two digester upsets occurred, these were the result of operational errors.

A 290 kg/day (640 lbs/day) accumulation of phosphate was calculated in the ponds because of the phosphate levels in the primary effluent and the digester supernatant. No increase was observed in the dissolved phosphate in the tertiary treatment plant influent, however. It is not known if the phosphate buildup will continue or would reach some equilibrium value.

Handling the alum sludge resulted in several operational problems, all of them related to the sludge's voluminous character and poor settling characteristics. The tertiary treatment plant was designed using water treatment plant design criteria, but, owing to the alum sludge characteristics, several changes were necessary. A baffle was installed between the flocculation chamber and the sedimentation tank. This was done to minimize the turbulence caused in the sedimentation tank caused by the flocculation paddles. Another change was to install a variable speed motor on the flight drive system. This change allowed the flight drive speed to be lowered to reduce turbulence and achieve better settling.

Recommendations

It may be worthwhile to redesign the flights in the sedimentation tank so that they do not remain submerged on their return travel. Following water treatment design practice, these had been designed to remain submerged at all times. However, this may be causing turbulence and dispersing the alum sludge. Any change that would result in thicker alum sludge concentration would improve the performance of the tertiary treatment process and yield higher plant efficiencies.

Sludge thickening devices could be used to achieve thicker sludges that could be fed directly to the digesters. Adding alum sludge directly to the digester would reduce the phosphates recycled to the ponds in the primary effluent. Although the digester supernatant might become higher in phosphates, the total phosphates recycled to the ponds would decrease. However, without thickening, this operation is impossible.

OPERATIONAL PROBLEMS

Prechlorination

Chlorination of the TTP influent (10 mg/l) increased plant capacity when Euglena algae became numerous. These motile algae are able to pass through the filters, which caused an increase in turbidity. Maximum plant flow under unchlorinated conditions was limited to about 1330 m^3/day (350,000 gal/day) when Euglena were abundant. Prechlorination destroyed the motility of the Euglena, causing them to "ball up", and increased the capacity of the plant by decreasing the number of Euglena passing through the filter.

Prechlorination also decreased the production of CO_2 by the bacteria in the sedimentation tank. This improved tank efficiency, especially in the warmer seasons.

Pipe Gallery Freezing

The original design of the tertiary treatment plant provided for an open pipe gallery. However, in this area temperatures in the winter can often go below freezing, and freezing would occur in the pipes and valves. In one instance, in January, the outside air temperatures dropped to - 16°C (3°F) or lower and a 5.24 cm (6-inch) diameter check valve was broken by ice. The tertiary plant was not running at that time. To correct this, the pipe gallery was covered for protection from the outside weather, and a heater installed, and freezing has no longer been a problem.

Sedimentation Tank Problems

As indicated before, two modifications of the sedimentation tank were made. A wooden baffle was installed between the flocculation and sedimentation chambers to reduce turbulence in the sedimentation chamber. Also a variable speed drive motor was installed on the collection flight drive. The original design speed of these flights was 91.4 cm/min (36 in/min). With the variable speed drive in operation, the collection flight was usually run at speed of 48.0 cm/min (19 in/min). This lower speed reduced the disturbance in the sludge blanket, and thus resulted in a better operation.

Duck Problems

When the tertiary plant was originally put into operation there was a recurring problem of plant shutdowns caused by ducks entering the plant influent line from the oxidation ponds. Throughout the two-year demonstration program, ducks entering and clogging the influent caused 54 tertiary plant shutdowns.

The clogging normally occurred at the meter. A screen installed over the intake substantially reduced the clogging although even after the screen was installed duck bones would occasionally be found clogging the intake meter. Although a smaller intake screen mesh might have been used, this was not done because clogging might then occur at the intake in the pond.

ECONOMICS OF OPERATION

Throughout the testing and demonstration program, data was accumulated on the costs of producing the reclaimed water. Particular attention was given to keeping operational expenses separate from those expenses associated with research and testing work.

Table 18 shows a breakdown by cost category and annual quarters of all expenses incurred in the operation of the tertiary treatment plant. Expenses associated with research and testing are not included. The cost categories are:

1. Salaries and Wages: this included supervision and fringe benefits.
2. Chemicals: this comprises principally alum and chlorine.
3. Repairs and Miscellaneous Supplies: this includes all tertiary plant repairs, miscellaneous supplies such as charts, lubricants, etc., and travel expenses.
4. Utilities: this is principally electrical power costs.

On the average, the costs were distributed as: salaries and wages, 44%; chemicals, 42%; repairs and miscellaneous supplies, 6%; and utilities, 8%.

The overall average total unit cost for producing reclaimed water throughout the two-year demonstration program was \$65 per thousand cubic meters (\$246/mg). Labor and supply cost increases due to inflation have not been considered independently in the analyses of these costs. However, although essentially the same quantity of water was produced in 1972 as in 1971, the overall unit cost in 1972 was \$67.20/1000m^3 vs. \$62.20/1000m^3 in 1971. This is a rise of approximately 8%, much of which was undoubtedly due to wage and supply cost increases.

Table 18 TERTIARY TREATMENT PLANT
OPERATING COSTS

Time Period	Total Discharge ($1000m^3$)	Costs (Quarterly Totals)				
		Salaries	Chemicals	Repairs & Misc. Sup.	Utilities	Total
Jan-Mar 1971	132**	$ 3,960 ($30.00)*	$ 2,360 ($17.88)	$ 385 ($2.92)	$ 710 ($5.38)	$ 7,415 ($56.17)
Apr-June	85	3,960 (46.59)	1,500 (17.65)	385 (4.53)	450 (5.29)	6,295 (74.06)
July-Sept	125	2,965 (23.72)	3,507 (28.07)	789 (6.31)	407 (3.26)	7,668 (61.34)
Oct-Dec	138	2,861 (20.73)	4,103 (29.73)	540 (3.91)	1,032 (7.48)	8,536 (61.86)
Jan-Mar 1972	87	2,486 (28.57)	1,657 (19.04)	154 (1.77)	439 (5.04)	4,736 (54.44)
Apr-June	99	2,580 (26.06)	4,083 (41.24)	95 (.96)	442 (4.46)	7,200 (72.73)
July-Sept	189	5,470 (28.94)	4,414 (23.35)	578 (3.06)	534 (2.83)	10,996 (58.18)
Oct-Dec	112	3,362 (30.02	4,851 (43.31)	491 (4.38)	1,119 (9.99)	9,823 (87.70)
Totals:	967	$27,644 ($28.59)	$26,475 $27.38)	$3,417 ($3.53)	$5,133 ($5.31)	$62,669 ($64.81)

Notes: * Cost figures in parentheses are the quarterly unit cost per 1000 m^3
** Conversion: 1 acre-foot = $1230m^3$

Purchased domestic water in this area costs \$42/1000m^3 for water produced by the local water district. Water is also imported through the Antelope Valley from the Feather River in northern California as a part of the California Water Project. The cost of this water is estimated at \$59.40 to \$63.60 per 1000m^3, if it were to be made available. While the costs of locally produced fresh water are lower, the supply of this water is limited. As compared to water from the California Water Project, the production cost of the tertiary plant water is fairly competitive. This is particularly true when the plant is discharging at or near the design capacity.

The quarterly cost data showed a slight relationship between the total unit operating cost and average daily discharge. This is shown in Figure 45. There is a slightly

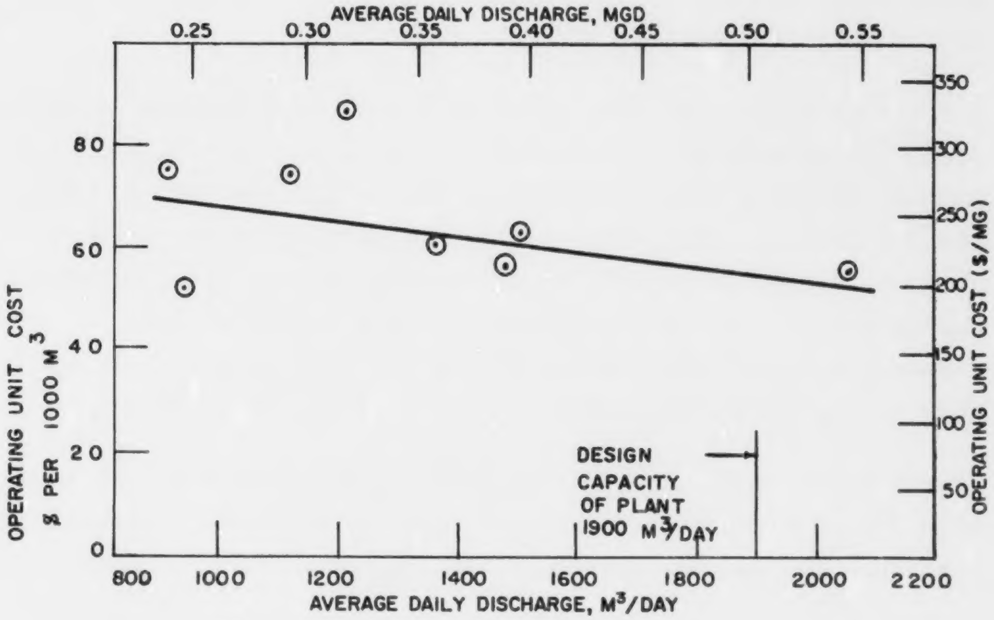


Figure 45 OPERATING UNIT COST vs. AVERAGE DAILY DISCHARGE 1971-1972

downward trend of lower unit operating costs with higher average daily discharge rates, although the correlation is not strong.

CONCLUSIONS

The tertiary treatment plant demonstration and testing program provided a valuable opportunity to analyze and correct the problems of the new plant, identify parameter ranges for optimum performance, and to obtain operational cost data. This program showed that the tertiary plant could successfully produce water meeting all quality requirements.

Optimum plant performance in terms of turbidity, phosphate reduction, alum costs, and pH was examined, and the effect of these parameters on plant performance has been described. No single set of operational parameter values could be depended upon to give the least cost of treatment at design flow. Instead, it was necessary to maintain the operational parameters within certain ranges to consistently produce the desired water quality.

A special study was conducted for the alum sludge, principally to determine its effect on the digesters and on the amount of phosphate buildup in the oxidation ponds. The study revealed that alum sludge, cosettled with primary sludge, would not upset or adversely affect the digester performance. While a buildup of phosphates in the oxidation ponds was indicated, there was no evidence that this would cause problems.

Operational cost data on the plant indicated that an acceptable final effluent could be produced at costs competitive with the estimated rates for California Water Project water.

SECTION VIII
DEMONSTRATION AND EVALUATION OF LAKES AND PARK SITES

INTRODUCTION

The performance of the recreational lakes at Apollo County Park was the final measure of success for the entire waste water reclamation and reuse concept. Of the many performance goals that these lakes were to meet, health requirements were the most important. The lakes were to be free from any health hazards from virus, bacteria, other organisms (e.g., carriers of swimmers' itch), or chemical contamination.

Because fishing was to be one of the main activities at this park, the lake waters had to provide a suitable environment for fish. The waters were to be free from any chemical contamination injurious to fish, and the environmental condition necessary for feeding, propagation, and protection had to be met. Finally, the fish had to be safe for eating.

In terms of appearance and aesthetics, the lakes were to be as clear as possible and odorless. Prevention of algae and plant growths was given particular emphasis as the water was derived from a sewage effluent rich in nutrients. Algae growths could also possibly threaten the fish by causing dissolved oxygen fluctuations, high pH levels and clogged gills.

Other performance goals were that the water was to be suitable for irrigational and fire fighting use, and that insects were to be controlled.

MONITORING PROGRAM

Purpose

An extensive monitoring program was set up to provide a comprehensive picture of the developing chemical and biological lake conditions throughout the start-up period. This would help to evaluate the lakes in terms of the operating criteria and would provide an early warning in preventing operating problems from becoming too serious. The program would also yield evidence on factors responsible for water quality trends.

Bacteria, virus, chemical and algae tests, entomological and ecological surveys, fish data collection, and the maintenance of flow and irrigation records made up this monitoring program. Field data was collected from February, 1971, through December, 1972. Some programs such as fish monitoring continued on into 1975.

Bacteria and Virus Tests

The Los Angeles County Health Services Department, Community Health Services, conducted a monitoring program for virus and bacteria levels. For the most part this monitoring program focused on the tertiary plant as this was the key link in the water reuse system. However, grab samples from the lakes were also tested occasionally.

Chemical Tests

The lake waters and the tertiary plant effluent were regularly tested for the constituents shown in Table 15 . Two samples were taken from each lake every two weeks for these tests. All samples were taken from the same designated points along the shorelines for uniformity.

In addition to these regular bi-weekly samples, lake profile samples were also taken. Using a small rowboat and a Kemmerer depth sampler, water samples from the surface, mid-depth, and one foot off the bottom were taken from each lake. Six sample points were used in each lake, and the samples were gathered bi-weekly on those weeks when the shoreline samples were not collected. These profile samples were each tested for temperature, turbidity, pH, alkalinity, carbon dioxide, and dissolved oxygen.

Los Angeles County Sanitation Districts personnel did the laboratory work in testing most of these samples, and the tests were conducted either at the Lancaster treatment plant or the San Jose Creek Laboratories. The remaining samples were tested by the County Engineer Department at their laboratory in Los Angeles.

Algae Tests

Each of the above shoreline or profile lake water samples was also examined for algae. Sanitation District personnel made cell counts (manual) and algae identifications for each of these samples at the Lancaster treatment plant laboratory. Only the free-swimming algae was counted in this way. Observations were made of the algae mats of *Anabaena* or *Spirogyra* that developed in the lakes, but no quantitative measurements were made of these.

Entomological and Ecological Survey

The Entomology Section of the County Health Services Department conducted periodic surveys of the park to observe and record the development of insect life and other biota important to the natural food chains and environmental conditions. Particular attention was paid to the presence or absence of midge larvae (*Chironomid*) and littoral vegetation. The littoral vegetation was of interest as a source of potential mosquito breeding.

Fish Studies

Because fishing was to be an important activity at this park, the initial fish stocks were carefully watched. Records were kept of the numbers and types of fish stocked and any known fish deaths. Biopsies were made on several fish by the State Division of Fish and Game, and laboratory testing was performed by the State Health Department and the Sanitation District laboratories.

Flow Records

Flow records were maintained throughout the monitoring program of the teritary plant effluent, irrigation water pumped, and lake levels. Flow meters were maintained both at the tertiary plant and on the irrigation system.

HEALTH REQUIREMENTS

Bacteria Studies

Samples for coliform bacteria tests were collected from the tertiary treatment plant every week. The sample location points were the tertiary plant influent, the filter effluent and the final tertiary plant effluent, located as shown in Figure 9. The tertiary plant influent sampling gives an indication of the bacterial load on the treatment plant. The results of the filter effluent sampling show the combined effectiveness of the flocculation, sedimentation, and filtration processes. Finally, the final effluent sampling gives the bacterial levels after the additional treatment steps of chlorination and detention.

After collection, the samples were chemically fixed with sodium thio-sulfate and delivered to the Community Health Services' public health laboratory for testing. About one hour elapsed between collection and testing, and the samples were not refrigerated for transit.

The samples were tested for the presence and most probable number (MPN) of coliform bacteria according to the procedures outlined in "Standard Methods"[6]. The multiple tube fermentation technique with lauryl tryptose broth and brilliant green lactose bile broth was used for presumptive and confirmed tests.

Figure 46 summarizes the results of these coliform bacteria tests. The influent bacterial load shows a marked change in December of 1971. Prior to that time, the median MPN/100 ml bacterial level in the plant influent was greater than 24,000. After that time the median drops to 430 MPN/100 ml. The reason for this is that around the first of December, 1971, the Sanitation Districts personnel altered the secondary treatment process by routing the flow through an additional oxidation pond before pumping it to the tertiary treatment plant. This increased the secondary treatment detention time by approximately 40 to 60 days.

The results for filter effluent and final effluent also show a drop after December, 1971. The median value for the filter effluent prior to December, 1971, is 60 MPN/100 ml; after that time the median drops to 7.8 MPN/100 ml. However, this improvement is no doubt caused by a number of factors in addition to an improvement in source water. Increased operator experience and the benefits of the plant optimization study also helped improve the plant effluent.

Grab samples from the Apollo Park Lakes were also collected. These samples were taken three times during 1972, and each time 13 samples were taken. The coliform bacteria counts for these ranged from 1.8 to 140 MPN/100 ml. The median value was 7.8 MPN/100 ml.

The bacterial study results were generally as expected. The pilot studies for this project, as indicated in "Final Report, Waste Water Reclamation Project for Antelope Valley"[3], revealed the effectiveness of the secondary process in producing high die-off rates for coliform, fecal

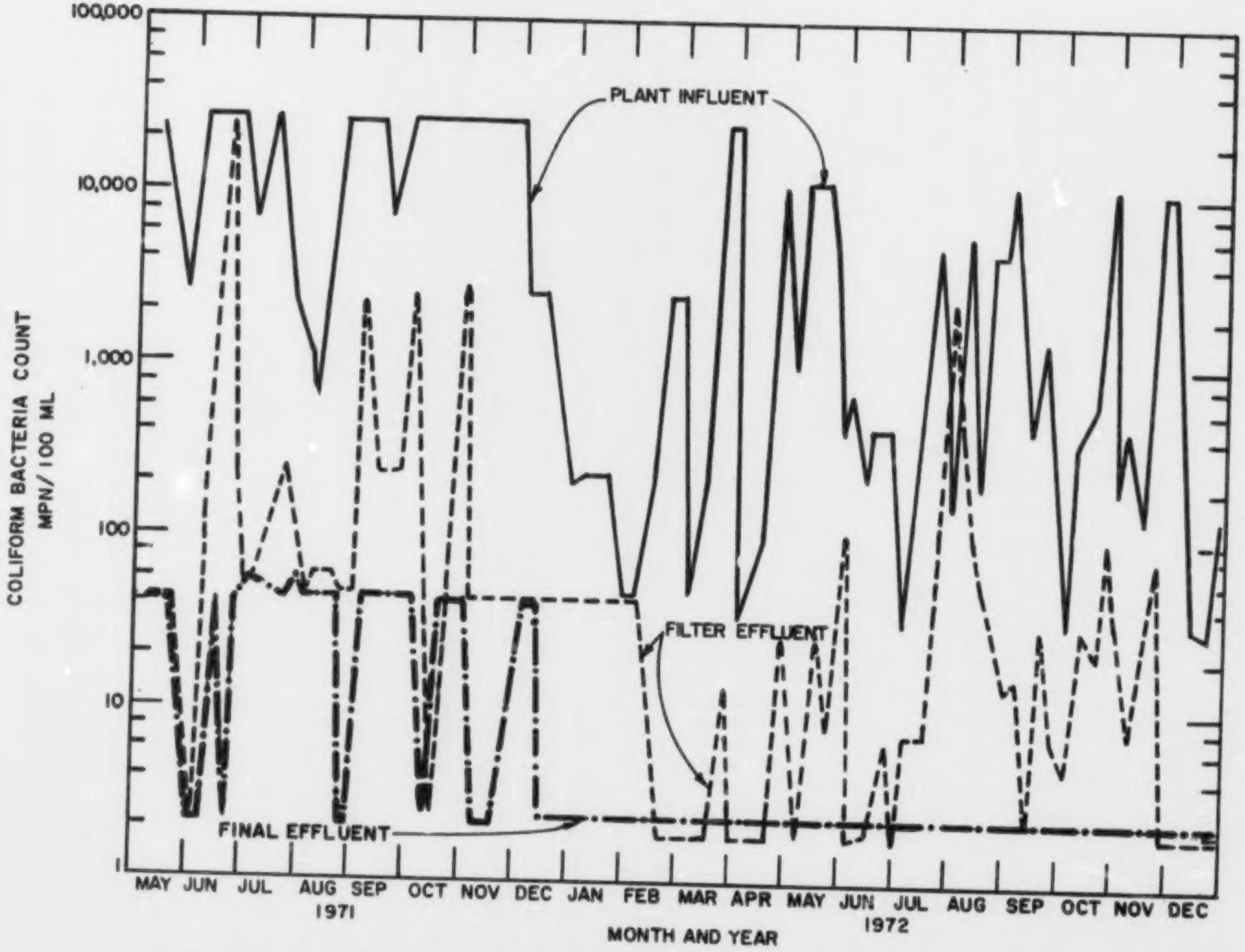


Figure 46 TERTIARY TREATMENT PLANT COLIFORM BACTERIA COUNT

coliform, and fecal strep bacteria. Somewhat higher bacteria counts were expected for the Apollo Lakes, as these would be exposed to contamination by birds.

Virus Studies

Three samples per week were also taken from the tertiary plant for virus testing. The sample locations were the same as for the bacteria tests. The virus samples were collected on swabs inserted in flow-through tubes installed on bypasses from the main flow lines. The swabs were inserted for 48 hours and flow from the sample point was pumped through the tube at a rate of 0.03 l/sec (1/2 gal per min). At the completion of the 48 hours, the swabs were removed and delivered to the Community Health Services' laboratories in Los Angeles. The swabs were transported in a plastic container without chemical fixing or refrigeration.

The test for virus was done by elution of the absorbed virus by change of pH and washing, concentration by centrifugation, decontamination, planting the button on growing tissue culture, incubation, and examination by microscope. The presence of any cyto-pathogenic effect was determined by a visual examination through the microscope. This testing method indicates only whether or not viruses were present and it provides no further quantitative information. However, because only once during this program was the presence of a virus detected, a more quantitative method was not needed. This method was chosen because it had been satisfactorily used at the Santee Project in San Diego County. This method has been reported in Askew, Bott, et al[7,8], "The Santee Reclamation Project"[9], and "Microbiological Content of Domestic Waste Waters Used for Recreational Purposes[10].

Throughout the entire testing program only one tertiary plant influent sample showed a positive cytopathogenic effect. No filter effluent or final effluent sample ever yielded a positive effect.

Conclusions

The effectiveness of the secondary treatment process and the tertiary plant in removing virus and bacteria was well demonstrated in this project. The project goal of consistently obtaining an effluent coliform bacteria level of less than 2.2 MPN/100 ml was easily met.

Routine monitoring of the bacterial and viral quality of the plant influent and effluent should be continued. Presently there are no nationally accepted procedures or standards for virus monitoring. Consequently, any virus monitoring program adopted for this plant will have to be kept flexible.

The bacterial quality of the water in the Apollo Lakes has consistently met the State of California "Standards for the Safe Direct Use of Reclaimed Wastewater in Irrigation and Recreational Impoundments"[11] for non-restricted recreational impoundments.

Also, in comparison to the normal bacterial requirements for bathing areas, the State of California "Laws and Regulations Relating to Ocean Water - Contact Sports Areas"[12] has a basic coliform MPN limitation of 1000 per 100 ml. The County of Los Angeles Public Health Code, Ordinance 7583, has a basic coliform MPN limitation of 500 per 100 ml for fresh water bathing areas.

Thus far, the lake water test results have been successful in meeting these bacterial quality standards. However, the number of samplings have been too few to draw conclusions, and additional sampling is needed.

Consequently, although the health agencies have approved the use of Apollo Park Lakes for restricted recreational use (Boating, fishing, etc.), no written approval has yet been given for non-restricted recreational use (body contact sports).

PERFORMANCE AS A FISH ENVIRONMENT

Introduction

As summarized in Table 12 of Section V, the California Department of Fish and Game stocked the new lakes in March, 1971, with 20 Channel Catfish, 50 Red-Ear Sunfish, and 100 Largemouth Black Bass. All the fish were adult size. These warm water fish were planted to determine their survival and propogation rates in the lakes, and for testing.

In December, 1971, 100 small Rainbow Trout were introduced to the lakes to determine their survival rates, especially during the hot summer months.

As indicated in the discussion of insects and crustaceans, a natural food chain developed and feeding apparently never became a problem. However, of the thousands of mosquito fish (Gambusia) planted for insect control, all were consumed by the larger fish within a short period.

To help improve cover and provide breeding sites, lengths of clay pipe 10.-, 20.-, 25.-,cm diameters (4-, 8-, and 10-inch diameters) and shallow and deep water gravel spawning beds were placed as shown in Figure 27. The growths of Zannichellia which developed in Lake No. 3 were probably also helpful in providing protective cover for younger and smaller fish, although these growths were objectionable from an aesthetic standpoint.

Discussion of Fish Environment

During the first month immediately after the initial planting of fish in March of 1971, 10 Largemouth Black Bass died and others were seen swimming sluggishly near the water surface. State Department of Fish and Game personnel investigated this problem, and fish and water samples were collected. The cause of the fish kill was concluded to be the result of a combined high ammonia and pH level. Ammonia had reach a level of 1.8 mg/l with a corresponding pH of 9.3. Also, some of the bass were weakened during transportation to the lakes, and this probably contributed to the kill.

At the time of this fish kill, all the fish were being held in Lake No. 3 and no new water was being added to this lake as all the influent to the park was then going directly to fill Lake No. 1. Lake No. 3 had been originally filled with water containing higher levels of ammonia. Because no new water was being added, the pH of the water in the lake was constantly rising. Apparently, a reaction of the water with the soil lining the lakes was causing this pH rise.

To remedy this problem, the incoming flow was routed directly into Lake No. 3 with the excess overflowing into Lake No. 1 to fill that lake. The influent water had a pH of about 6.5 and peak ammonia levels of 2.0 to 4.0 mg/l. By May 1971, as the weather warmed up, the ammonia level dropped to zero. By flushing Lake No. 3 in this way, the ammonia and pH levels dropped and no further fish kills have occurred.

Also, because of this problem and because the tertiary treatment plant process does not affect ammonia, the operation of the secondary treatment (oxidation ponds) was thereafter carefully controlled to produce a plant influent with a low ammonia concentration. This has been accomplished by storing excess oxidation pond water during the still warm autumn months for tertiary treatment and pumping to the lakes during the colder winter months.

After this initial and only fish fill, the fish have thrived. By summer and fall of 1972, many small fish were observed in the lakes indicating that reproduction was occurring.

Six Rainbow Trout were the first fish netted in February of 1973 for testing. These fish, when planted in December of 1971, were from 10 to 15 cm (4 to 6 inches long), and during their 14 months of life in the lakes had grown to 46 to 56 cm long (18 to 22 inches) and weighed from 1040 to 1450 gm (2.3 to 3.2 pounds). It is interesting to note that the Rainbow Trout can survive all year round in the lakes as the water temperature does not exceed 23°C (74°F). The other fish in the lakes similarly thrived and reproduced as pictorially shown in Figures 47 and 48.

The State Department of Fish and Game examined and conducted biopsies on the fish caught from the lakes in February of 1973. No parasites were found in or on the specimens examined, no systemic bacteria were found in the kidney cultures and the fish appeared to be in good overall condition.

Prior to the February 1973 fish biopsy tests, the County Department of Health Services in November 1972 had reported that the results of their analyses of samples over a considerable time indicated that the water and the process are adequate to assure compliance with the "Statewide Standards for the District Use of Reclaimed Wastewater for Irrigation and Recreational Impoundments"[13], with the recreational use limited to fishing, boating, and other non-body-contact water sport activities.

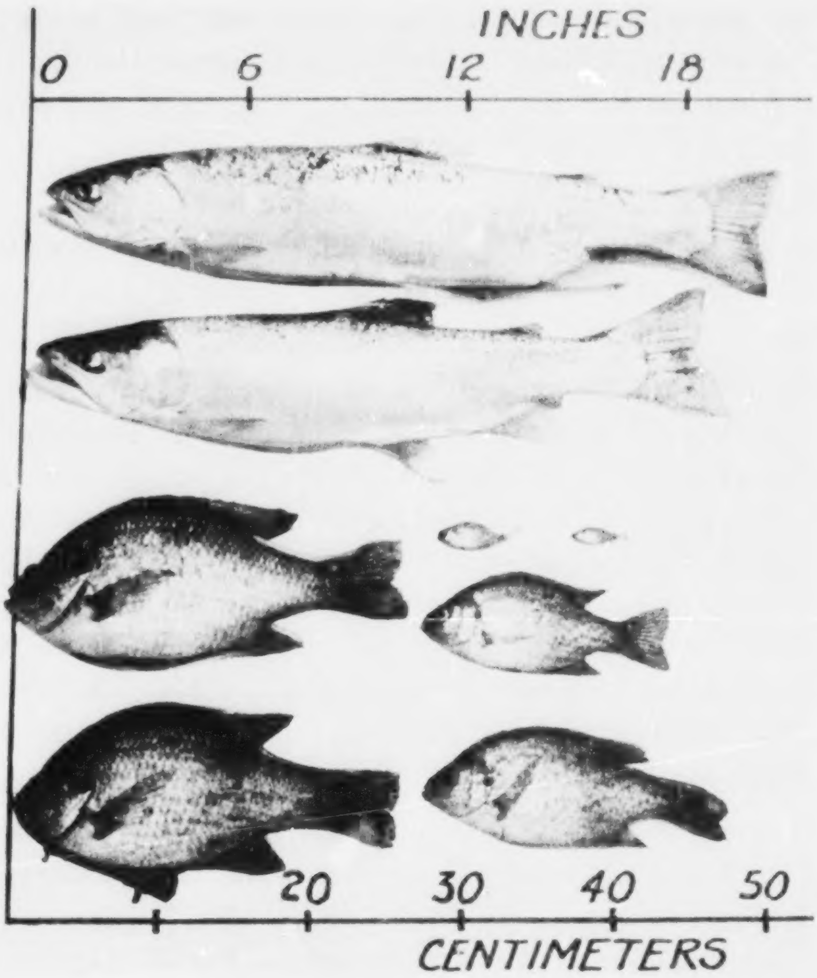


Figure 47 RAINBOW TROUT AND RED EARED SUNFISH
REMOVED FROM APOLLO LAKES, APRIL 9, 1974

Therefore, only one last test was necessary to open the lakes to public fishing. On March 28, 1973, one large fish sample was delivered to the State Department of Health Laboratory in Los Angeles to test for heavy metals, pesticides and herbicides. The Rainbow Trout tested, which had been in the lakes for 14 months, was found to contain 2.0 mg/kg of mercury which is well above the maximum allowable concentration of 0.5 mg/kg. This was the only element found in this specimen which neared the maximum allowable limit. Because

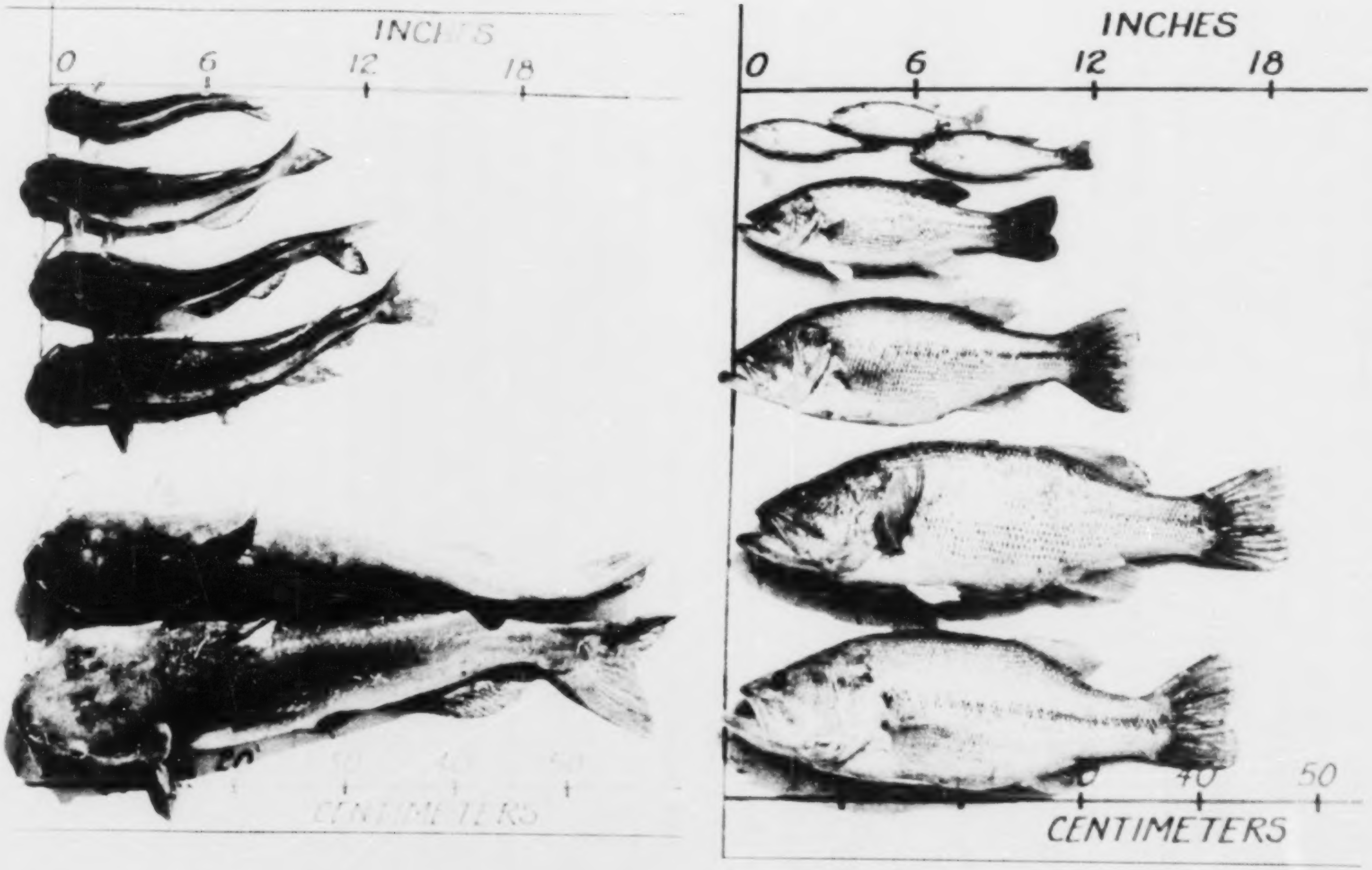


Figure 48 CHANNEL CATFISH AND LARGEMOUTH BLACK BASS REMOVED FROM APOLLO LAKES, APRIL 9, 1974

of this result, it was necessary to delay opening of the lakes to public fishing until complete further testing could be accomplished and the test data analyzed.

Mercury Analysis of Fish

Since the initial test in February 1973 indicated a high concentration of Mercury, a comprehensive investigation was begun to test more fish samples and also to determine the source of the mercury in the environment. The survey included a study of mercury moving up the food chain of the lake biota.

Table No. 19 indicates the results of the testing on the 32 fish samples.

A well known source of mercury contamination is the methylation of the metal in sediments on lake bottoms. This is considered to be the prime source of mercury in the food chain. Methylation is the process by which inorganic divalent mercury (Hg^{++}) is converted to either monomethyl mercury (CH_3Hg^+) or dimethyl mercury (CH_3HgCH_3). Almost any form of mercury can directly or indirectly be converted to methylmercury by first being oxidized to divalent mercury. In order to accomplish this, redox potential of about 80 millivolts is required (D'Itri[14]). In a well oxygenated system, such as the Apollo Lakes, the redox potential is on the order of 850 millivolts; more than adequate to accomplish the conversion.

Methylation is primarily accomplished through an enzymatic biological process involving the transfer of a $-CH_3$ group from a form of vitamin B_{12} known as methylated cobalamine (Gavis and Ferguson[15]). Methylated cobalamine can be regenerated indefinitely by the methylating bacteria.

Table 19

MERCURY ANALYSES OF FISH IN APOLLO COUNTY PARK

(Total Fish Tested: 32)

Fish		Length		Weight		Date Tested	Total Months In Lakes	Mercury mg/kg
		Ins.	cms	lbs.	Gms.			
Rainbow Trout	1	19*	48.2*	2.6*	1200*	3-28-73	15	2.0
	1	19	48.2	2.5	1125	5-25-73	18	2.28
	1	19	48.2	2.9	1300	"	"	1.92
	1	17	43.1	2.3	1061	"	"	2.66
	1	18¾	47.8	2.1	964	"	"	3.17
	1	19	48.2	3.0	1346	"	"	1.92
	1	19	48.2	2.0	890	4-9-74	28	2.9
Channel Catfish	1(a)	8*	20.4*	0.20*	90*	5-4-73	2 min.*	0.32
	4(a)	11to 13	28 to 33	0.60 to .83	274 to 380	5-25-73	3 min.	Aver. 0.25
	10(a)	8 to 10	20 to 25.4	.19 to 0.32	86 to 147	5-25-73	3 min.	Aver. 0.46
	1	24¼	61.5	4.0	1828	4-9-74	36	1.4
	1(a)	11¼	28.6	.50	226	"	13 min.	0.9
Red-Ear Sunfish	1	8¼	21	.68	311	4-9-74	36	1.0
	1(b)	5½	14	.32	144	"	24*	0.4
Largemouth Black Bass	1	15*	38*	1.5*	700*	5-8-73	25	2.95
	1(b)	11	28	.57	258	5-25-73	18*	3.0
	1	15¾	40	1.6	725	"	26	0.88
	1	17.9	45.4	3.0	1352	4-9-74	36	2.0
	1(b)	13¼	33.6	1.1	478	"	24*	·3.5
	1(b)	5	12.7	.04	20	"	12*	0.9

* Indicates approximation

(a) Indicates fish born in lakes or plant of 3-1-73

(b) Indicates fish born in lakes

Mercury may also be methylated nonenzigmatically although this is not a major source (Nelson, et al[16]).

The methylation of mercury is reported to be a function of redox potential, mercury concentration, microbial activity, temperature and pH (Langley[17]). As mentioned before, the redox potential controls the conversion of various forms of mercury to divalent mercury from whence it then can be methylated. The initial products of methylation are both dimethyl and monomethyl mercury. Dimethyl mercury is less toxic than monomethyl mercury and also, more volatile. Thus, dimethyl mercury is more likely to escape to the atmosphere.

At high mercurial concentrations, the formation of monomethyl mercury is favored. Methylation is not inhibited due to the toxic effects of mercury until concentrations on the order to 500 ppm are reached (Fagerstrom and Jernelov[18]). One of the amin parameters that controls microbial activity is temperature. As the temperature increases, so does the rate of microbial activity. As the rate of microbial activity increases, so does the rate of methylation. Furthermore, methylation will proceed at a much faster rate under aerobic conditions than under anaerobic conditions. Finally, under alkaline conditions, the formation of dimethyl mercury is favored. Under acid conditions, the dimethyl mercury resulting from methylation decomposes to monomethyl mercury resulting in a higher proportion of less volatile monomethyl mercury and a greater detention time for the mercury in the system

In order to classify sediments according to organic content, Ballinger and McKee[19] have developed the Organic Sediment Index (OSI). This is a qualitative parameter calculated as the product of the percent organic carbon and percent organic nitrogen in a sediment sample. Furthermore, it has been found that the rate of mercury methylation is directly related to the OSI (Langley[17]).

Consequently, to determine the ability of the bottom sediments of the lakes in Apollo Park to methylate mercury, four sediment core samples were taken and analyzed for mercury. Two of the samples were also analyzed for percent organic carbon and percent organic nitrogen to determine the OSI of the sediments. The sampling points are illustrated on Figure 49. Sampling point "A" is located in the proximity of the main discharge point of the polished waste water into the lakes. The other three sampling points represent typical bottom conditions.

Although the samples taken from the bottom of the lakes consist of natural soil, they are not from the same environmental setting as the natural soil elsewhere around the park. Therefore, three grab samples of natural soil were taken from outside the park. These three samples (points 1A, 2A, and 3A on Figure 49), were taken on the upwind side of the park. This was done to determine what the mercury concentration is in the material that is carried across the lakes by the wind.

Grab samples were also taken of the soil inside the park since different soil conditions exist here (natural soil mixed with gypsum, chicken manure, and sludge) and also, different environmental conditions because of watering practices. Sampling points are shown in Figure 49. Two additional samples were taken of the sludge from the bottom of oxidation pond No. 2 of the District 14 Water Renovation Plant. This was not the same pond from which the sludge used in Apollo Park was taken, but represented the oldest sludge in the plant, being deposited in the last two years.

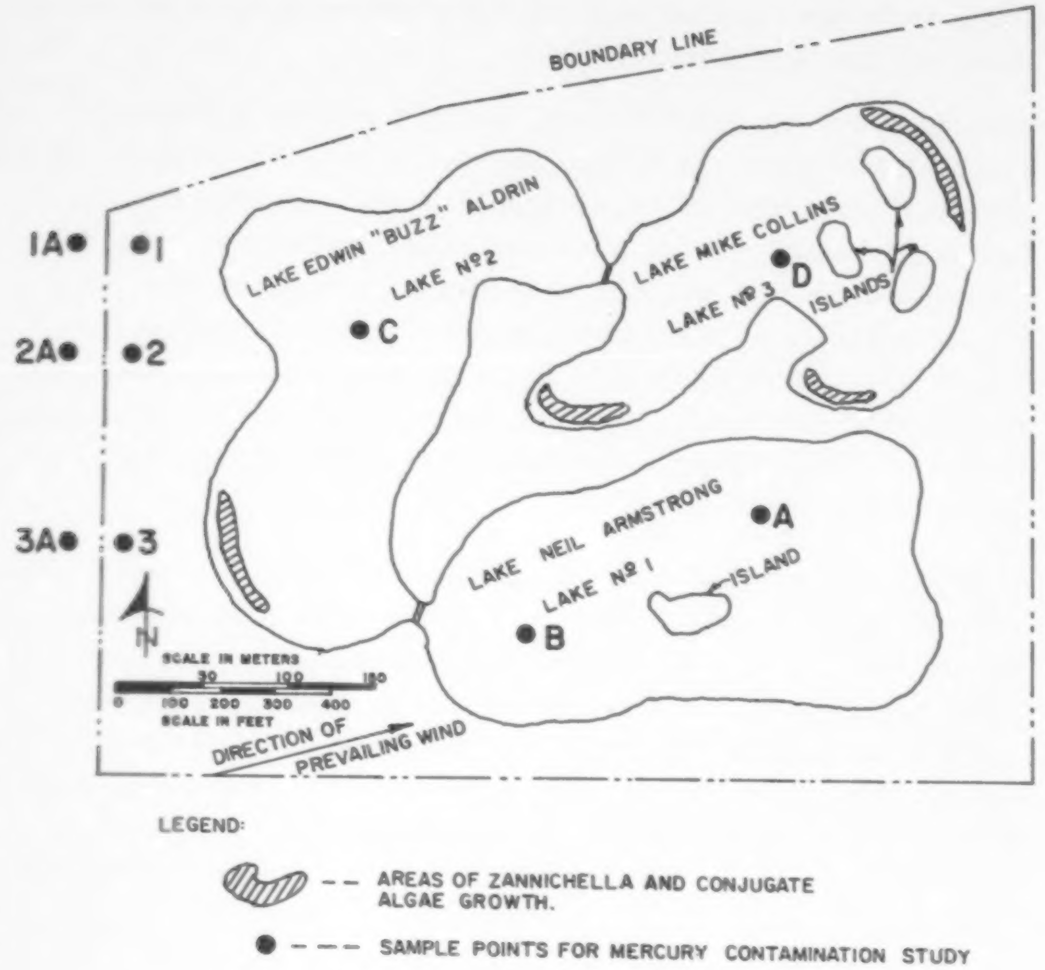


Figure 49 PREDOMINANT GROWTH AREAS FOR AQUATIC PLANTS AND MATTED FILAMENTOUS ALGAE

To determine the presence of mercury in the food chain in the lakes, samples were taken of the biological life. Each lake was dragged with a #20 algae net (0.0662 mm or 0.003" aperature). A sample of organisms in the aquatic weeds found in Lake No. 3 was also taken and finally, a crayfish obtained from the park officials was also analyzed. Sampling of the benthic organisms was also attempted, but due to improper sampling equipment, this phase of the program was discontinued. The samples were all stored in a freezer prior to transport to the lab.

The results of the sampling program, including the water, conducted at Apollo Park are shown in Table 20.

The samples taken from the bottom of the lakes were sandy in nature and fairly uncohesive except for the surface sample taken from Lake No. 3. This sample was divided into three portions to see how the mercury concentration varied with depth. The surface sample, about 6 mm (1/4") in thickness, consisted of a black sludge-like material. The middle sediment and the deep sediment samples, both about an inch in depth, were of the same sandy consistency as the samples taken elsewhere of the lake bottom. The other soil samples consisted of sandy material also; those inside the park were more cohesive than the others because of the soil conditioners that have been added.

The relative concentrations of mercury in the soil samples is as expected. The samples taken from the lake bottoms, being in an environment conducive to methylation, have much less mercury in them than the samples of natural soil taken outside the park. Similarly, the soil samples taken inside the park are lower in mercury concentration than the soil outside the park illustrating the probable effect of the addition of the soil conditioners and the leaching.

The concentration of mercury found in the samples of sludge from the oxidation pond are significantly high. However, it is doubtful that the dried sludge used as a soil amendment on the park grounds actually contained any mercury. The reason for this is that there is a rapid formation of volatile dimethyl mercury when wet, organic, mercury contaminated sediment is exposed to the air (Jernelov and Lunn[20]).

The values for the Organic Sediment Index are very low;

Table 20

MERCURY ANALYSES OF SOIL, BIOTA, AND LAKE WATERS

	Sample Location	Sample Type	Mercury Content mg/kg
1A	Outside of Park to West	Soil	0.240
2A		Soil	0.880
3A		Soil	0.851
1	Inside Park, West Side	Soil	0.100
2		Soil	0.391
3		Soil	0.252
A	Lake No. 1	Sediment	0.531
B	Lake No. 1	Sediment	0.212
C	Lake No. 2	Sediment	0.101
D	Lake No. 3	Surface Sed.	0.197
		Middle Sed.	0.343
		Deep Sed.	0.143
	Oxidation Pond No. 2 S.W. Corner	Sediment	0.509
	Oxidation Pond No. 2 Between Dischg. Pts.	Sediment	0.547
	Lake No. 1	Zooplankton	1.59
	Lake No. 2	Zooplankton	0.704
	Lake No. 3	Zooplankton	1.84
	Lake No. 3	Amphipods	0.237
	Apollo Lakes	Crayfish	0.099
	Lake No. 1	Water	<0.001 mg/l*
	Lake No. 2	Water	<0.001 mg/l*
	Lake No. 3	Water	<0.001 mg/l*
	Tertiary Plant Effluent	Water	<0.001 mg/l*

* Analyses conducted by State Department of Health, April 30, 1973.

0.00262 to 0.00647. This agrees with the OSI's calculated by Ballinger and McKee[19] for sandy sediments. However, sediments with indexes this small should not methylate any significant amount of mercury. Furthermore, the pH of the water at the bottom of the lakes averages between 8.1 to 8.4 and the temperature ranges from 3-21°C (38-70°F). This would indicate that dimethyl mercury is the favored end result of the methylation process of which a large portion should be volatilized. Also, the temperature range indicates that the methylation rate is not significant during the winter months of the year.

The average concentration of mercury is the sediments is only 0.254 mg/kg. The average concentration of mercury in the natural soil from outside the park is 0.657 mg/kg. This implies that almost 2/3 of the mercury originally in the sediments has escaped over a period of less than three years. Further studies are needed in this regard as this is an extremely fast rate.

Another possible source of mercury is from the natural soil outside the park. The wind carries an undetermined amount of this material and drops it in the lakes. The data indicate that this material contains a large amount of mercury. Because of the high redox potential of the lake water, this mercury would be quickly oxidized to inorganic divalent. mercury if it wasn't in the form already. Inorganic divalent mercury is preferably lipid soluble and has a greater affinity for sulfide sulfur. Many of the substances that constitute protoplasm contain sulfhydryl groups (-SH). Therefore, the affinity of mercury for sulfide sulfur does not only occur with organic matter such as humus, but also with living organic matter such as plankton (Gavis and Ferguson[15]).

A third possible source could be surface runoff from the park soil. This has been minimized by a diversion ditch and therefore is probably insignificant.

The zooplankton taken from the lakes with the algae net consisted almost entirely of Daphnia. An attempt was made to separate the larger organisms out by filtration through a larger mesh netting, but the mass was so dense that this proved impossible. Due to the warm environment, the lakes have been very biologically active. Daphnia is a filter feeding crustacean that feeds on algae. It is reported to be able to magnify the concentration of mercury over that of the water it is in by a factor of 3570 (Hannerz[21]). The concentration of mercury in the secondary effluent from County Sanitation District 14 has never exceeded 0.0003 mg/l. The State Public Health Department reported the water in Apollo Park to contain less than 0.001 mg/l (see Table 20). Assuming that the actual level of mercury in the water is somewhere in between and that the average concentration of mercury in the Daphnia is 1.38 mg/kg, the magnification factor is between 1380 to 4600.

The organisms found in the weeds in Lake No. 3 were mainly detritus feeding amphipods. Mercury is excreted at a very slow rate from fish and consequently, it is not surprising to find the mercury level in these organisms to be lower than in the Daphnia. The mercury concentration factor for the amphipods is between 237 and 790. The crayfish was the only one ever found in the lakes and how it got there in the first place is a complete mystery. The mercury concentration factor for the crayfish was between 100 to 330.

Fish may concentrate mercury in a number of different ways, depending on the species of the fish, how long the fish has been in the mercury-polluted environment, the extent of the mercury pollution, the metabolic rate of the fish, the source of food, the age and size of the fish, and the epilthelial surface area of the fish (Wallace, et al[22]). These variables are only qualitative since environmental interaction is so complex. However, the data in Table 19 bears this out. The bass and trout taken from the Apollo Lakes have higher mercury concentrations than the catfish. This is for a number of reasons. First, the trout are plankton feeding fish that were planted in the lakes on December 22, 1971. The bass, planted on March 16, 1971, generally feed on other small fish and aquatic insects. Bass fingerlings, however, feed more on zooplankton, filtering them out of the water through their gills (the epilthelial surface). The catfish are bottom feeders eating mainly detritus and aquatic insects. Also, it is felt that because of their size and weight, many of the test fish are part of the group of catfish that were planted in the lakes on March 1, 1973. Therefore, because of their age and feeding habits (trophic level) the mercury concentrations in the catfish are lower.

The two bass sampled on May 25 present an interesting paradox. The longer, heavier specimen has only 0.88 mg/kg of mercury in its flesh while the shorter, lighter specimen has 3.0 mg/kg of mercury. From its size and weight, the larger fish probably belongs to the group of bass originally stocked in 1971 or to the first spawning which occured shortly after stocking. The lighter fish is most likely from the bass spawned in 1972. This discrepancy in mercury concentration probably exists because the younger bass has been feeding on zooplankton which it can filter out of the water through its gills. The gill rakes of the adult bass are too large to catch these small organisms. Consequently, adult bass feed on other small fish (Gambusia, sunfish, and bass fingerlings) and aquatic and terrestial insects. The small fish planted in the lakes in 1971 were probably eaten by the bass long before they could concentrate any mercury.

Therefore, because the larger bass have been feeding on a less contaminated food source they have maintained a lower level of environmental equilibrium with respect to mercury.

Just as with the smaller organisms the fish also have an accelerated metabolic rate as a result of higher temperatures. This is best illustrated by the catfish. When the smaller fish were planted in March of 1973, they weighed on the average 65 grams and were 12 to 15 cm (5 to 6 inches) in length. The average weight of the catfish sampled in May is 172 grams and the average length is about 25 cm (10 in.). The background mercury concentration in fresh water fish, although difficult to assess, is assumed to be 0.20 mg/l or less. The average mercury concentration in the catfish after three months of exposure to a mercury-polluted environment is 0.40 mg/l, at least twice over normal background.

All incoming water to the Apollo Park Lakes is either evaporated or used for irrigation. Consequently, almost all of the mercury removed from the sediment or water by any organism will eventually find its way back into the sediments when that organism dies, settles to the bottom, and decomposes. Mercury from decomposed matter again enters the ecosystem in the form of inorganic mercury.

Before any course of action is taken, a more comprehensive sampling program should be conducted. There is a question concerning the validity of the natural background concentrations of mercury found in the west side of Apollo Park. No one has conducted a mercury survey on the soil in the Antelope Valley. However, concentrations found appear unusually high. Error may have been introduced through sampling techniques or method of analysis. This is emphasized by the one sample showing only 0.240 mg/kg as compared to the other two (0.880 mg/kg and 0.851 mg/kg). However, all three of these samples are considerably higher than expected. Background mercury levels in soil have been reported to be between 0.050 to 0.080 mg/kg (Shaklette, et al[23] and Tunnell[24].) The discrepancy could also be caused by previous environmental conditions. Apollo Park is located on the east side of the General William J. Fox Airfield. This is the downwind side of the airfield. The field has been sprayed with various weed killers for years to control weed growth. Although the weed killers presently used do not contain mercury, those used in the past may have. Therefore, it is recommended that a more thorough soil survey be conducted to confirm those concentrations found before and to see if the high concentrations are, in fact, a local condition caused by the airport.

Secondly, it is not known how much mercury is actually entering the lakes as a result of the "wind load." It is recommended that a sampling program be carried out in an attempt to measure this wind load. By knowing how significant the wind load is and whether the high soil concentration is local, a course of action can be taken.

Interim Fishing Program

Because the testing program indicated that the mercury contamination in the fish is a result of mercury methylation from the soils and sediments in the lake and that the methylated mercury is then passed through the food chain to the fish, it was necessary to establish an interim program so that the park could be opened to fishing.

As there is a plastic lining covering all lakes, the amount of mercury that can be methylated is limited by the 30 cm (1 foot) of earth cover over the lining and the amount of mercury returned as organisms in the water die. Therefore, at some point in time, the process should be slowed and then terminated. At such time, the only additional source of mercury will be from soil either washed or blown into the lakes. At this time, it cannot be determined if the amount of additional sources of mercury will be sufficient to cause problems. As washed in soils can be controlled, a program to determine quantities of mercury that might be blown into the lakes will be initiated.

However, until the mercury concentrations can be reduced to safe levels, an interim fishing program was initiated with approval of the health agencies. This program was established to control mercury contamination of the fish by a controlled fishing and stocking program consisting of two main parts: kill and remove all existing contaminated fish and introduce fish that will not become contaminated.

On April 9, 1974, all of the remaining hundreds of fish were killed by application of "Rotenone", collected, and hauled to a safe point of disposal. A total of 1140 kg (2500 lbs) of fish were removed which was twice the weight of fish that were previously planted since March of 1971. It was quite evident that the warm water species abundantly thrived and reproduced, and as many as five generations of fish were noted.

The "Rotenone" vaporized within three days, and the lakes were safe for commencing the new fishing program.

Only Rainbow Trout are now stocked every two weeks in the lakes because of the following reasons:

1. They are readily available from hatcheries near the Antelope Valley area.

2. They will not reproduce.

3. They will provide good test fish.

4. They are easily caught. From experience throughout the State, nearly all planted trout are caught in the first five days, and only 2% remain uncaught after the first week. Therefore, it would be a rare specimen to survive long enough to become contaminated above the approved mercury limit.

5. They can survive as long as the water temperature remains below 26°C (78°F).

A few trout are collected once a month at the time of stocking to determine background levels of mercury. Also, several trout from each plant are tagged so that a determination can be made on how long they remain in the lakes. A few of the tagged fish are placed in a floating cage in the lake where they can periodically be easily netted for mercury contamination tests. In this way, mercury uptake and concentration can be determined in the fish.

ALGAL GROWTH

Introduction

Special attention was given to algae growth problems in this study. Because of the high nutrient levels normally found in sewage treatment plant effluents, algae blooms can be a serious problem. The prevention of this problem was one of the major objectives of this program.

Algae blooms can, if large enough, be detrimental to fish as they can produce severe diurnal fluctuations in dissolved oxygen, clog fish gills, and cause high pH levels. Excessive algae growths are also unwanted from an aesthetic viewpoint. High turbidity, unsightly mats of filamentous algae, or, in some cases, bad odors may result.

The pilot studies for this project, as indicated in Final

Report, Waste Water Reclamation Project for Antelope Valley[3] indicated that meeting the water quality standards outlined in Table 2 would effectively prevent serious algal regrowth problems. The algae studies of this program were intended therefore to verify the conclusions of the pilot studies, and to determine from the full scale system what factors were responsible for algae growth in these lakes.

These algae studies proceeded along two main avenues. First, a field data study was conducted, monitoring lake and effluent water data. This would provide an early warning of unwanted algae conditions, and the data thus produced could be reviewed for any apparent relationships between water quality and algae growth. Secondly, a laboratory-scale algae nutrient study was made to identify the growth limiting nutrients and the growth potential for these lakes. This study was conducted by Dr. Jan Scherfig of the University of California, Irvine.

Field Data Studies

It is well known that algae will grow and multiply in a lake if the proper environmental conditions are met. These include temperature, pH, sunlight, and nutrients (phosphates, nitrogen, and trace nutrients). The same relationships apply in the case of these lakes. The objective of this study, however, was to determine the quantities involved. That is, how much of an algae problem will develop, how much and in what proportions is algae growth affected by the environmental conditions, and to what level can the nutrients be controlled?

To help answer these questions an extensive field data study was undertaken. Water samples were collected weekly for algae counts, and chemical analyses were made on a bi-weekly frequency. Lake profile data was also collected on a bi-weekly frequency. In the lake profile data, algae counts, DO , temperature, turbidity, pH, alkalinity, and CO_2 were measured at various depths throughout the lakes.

Algae Types

The field data study was concerned principally with free-swimming algae or phytoplankton. The term, algae, as used in this report shall refer only to free-swimming algae unless filamentous or conjugate algae is specified.

Chlorella was the most commonly found algae. Of all the times samples were taken, Chlorella was found 71% of the time. The next most commonly occurring algae was Chlamydomonas which was found in 49% of the samples. The following Table 21 lists all the types of algae found and the frequency with which each type was found. Algae samples were collected on 67 separate days throughout the period.

Although Chlorella was the type of algae most frequently seen, some of the major blooms were caused by the other types. For example, a Westella bloom that was measured up to 88,000 cells/ml occurred in August, 1971. An Oocystis bloom of at least 72,000 cells/ml occurred in July of 1972, and in March of 1971 a bloom that was approximately 50% Nitzchia and 50% Chlorella reached a level of at least 110,000 cells/ml.

Figures 50 and 51 show graphs of the algae counts for each month for 1972. Algae data was maintained for 1971 also, but this has not been plotted because not all lakes were filled then. 1972 was the first year of full lake operation. Because of the fluctuations in the algae cell concentrations they are likely to be higher than those recorded. However, a rational estimate of the true average cell counts for any month can be made by this method. Be-

Table 21 ALGAL FREQUENCIES IN APOLLO COUNTY PARK LAKE WATER

Algae Type	Frequency of Occurrences, as %*
Chlorella	71%
Chlamydomonas	49%
Oocystis	29%
Navicula	27%
Coelastrum	20%
Schroederia	17%
Nitzchia	17%
Ankistrodesmus	12%
Cocciod	10%
Scenedesmus	10%
Closteriopsis	5%
Pediastrum	5%
Cyclotella	Less than 5%
Planktosphaeria	" " "
Sphaerocystis	" " "
Chromulina	" " "
Chlorogonium	" " "
Westella	" " "
Stauroneis	" " "
Gloetanenium	" " "
Nannochloris	" " "
No Algae Found	5%

*For example, of all the days that algae samples were collected, Chlamydomonas was found 49% of the time. The above summary is based on the results of all algal tests made in the period February, 1971, through December, 1972.

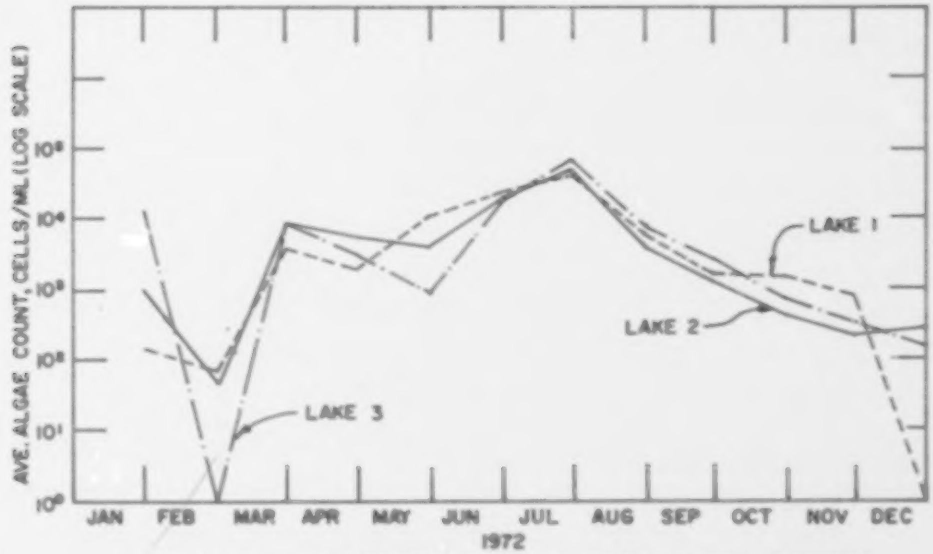


Figure 50 COMPARISON OF ALGAE CELL COUNTS BETWEEN INDIVIDUAL LAKES

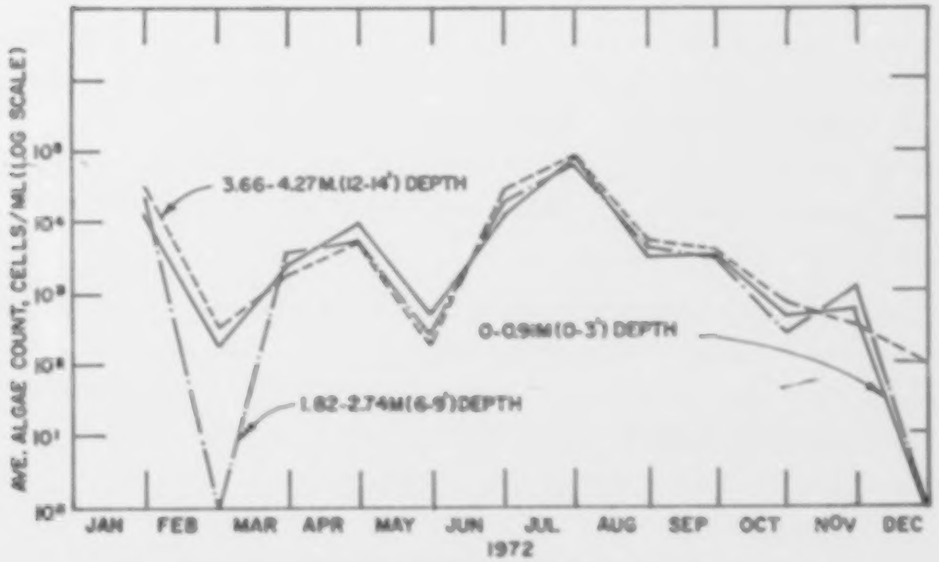


Figure 51 COMPARISON OF ALGAE CELL COUNTS AT VARIOUS WATER DEPTHS

cause these algae cell count averages fluctuate so widely (100 to 65,000+ cells/ml) the graph is drawn on a semi-logarithmic scale.

Variations With Location and Depth - The data was examined for variations in algae cell count between individual lakes and at different water depths. There was no consistent variation in the algae cell count with respect to depth, or between individual lakes. In fact, as can be seen in Figures 50 and 51, which show the algae counts at various depths and individual lakes, there was usually very little variation at all in the algae counts.

Filamentous and Attached Algae - Matted filamentous algae also appeared in the lakes. The algae types were principally Spirogyra, Anabaena, and Sirogonium. These algae types grew mainly in the shallower and wind-protected areas of Lake No. 3. The quantity of filamentous algae which occured was not measured, although it did appear to remain at a stable level.

From the very first weeks that water was put into the lakes, growths of Stigeoclonium Tenue, and similar types of blue-green algae appeared. These were green and blackish fuzzy growtns attached to the rocks along the shoreline. The growths were usually sparse, and never more than about one tenth of an inch thick.

The populations and zonation of these attached algae types varied seasonally. For example, in June, the zonation of these algae was particularly conspicuous with the blue-green algae forming a black band at the water level. Later in the summer the zonation became less conspicuous, and the Stigeoclonium decreased considerably probably due to damage from high light intensities and fluctuations in water level.

Aquatic Plants

Algae growth cannot be considered apart from the aquatic plant growth, since these two types of biota compete for many of the same nutrients. Aquatic plants did grow in significant amounts in these lakes, the principal species being *Zannichellia palustris*.

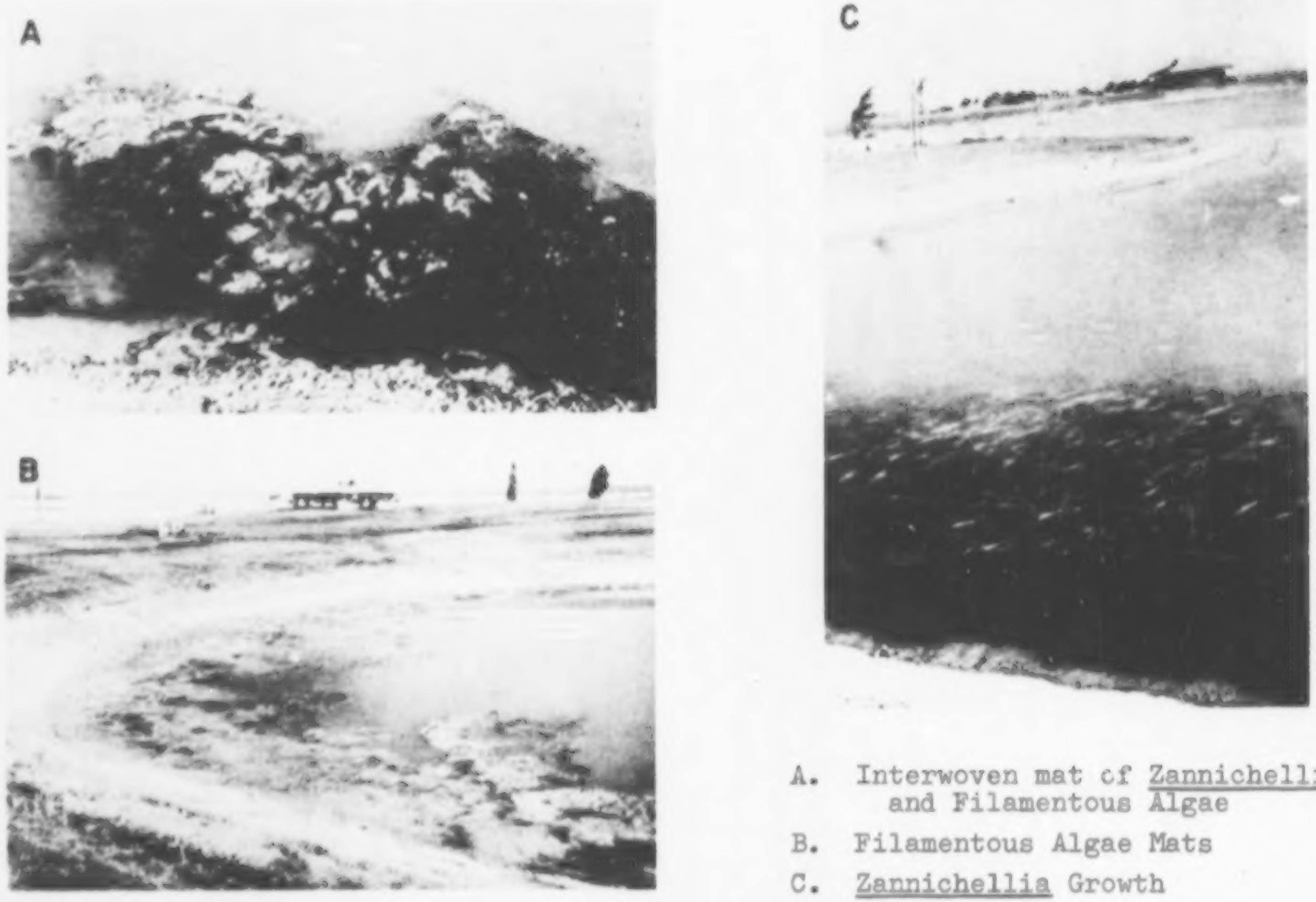
Zannichellia occurs throughout California in standing or very slow-moving alkaline or saline waters. It is said to occur between March and November in most locations but such statements overlook completely the persistence of the prostrate rhizomatous parts of the plants, and refer only to that part of the plant which occurs above the substrate. The rhozome perennates from one season to the next with upright stems developing from it at intervals along its length. The long-lived rhizome serves as a means of persistence and spread and in most of California upright stems are formed annually, in the spring, and disintegrate in the fall.

For the Apollo Park Lakes, in June this species occurred extensively in shallow water along the margin of Lake No. 3 forming a dark green belt of vegetation, 3 to 6 feet in extent, but almost totally submerged. Only a few portions of stem and leaf appeared above water surface although this was sufficient to provide a landing surface for insects and a trap for floating debris. By July the plants were flowering and seed had set in abundance. Some degeneration had also taken place so that the belt of vegetation was now an unpleasant brown fuscous color. Decomposition than proceeded rapidly so that by September most of the erect upright shoots had died back to the prostrate rhizome or only a few inches of persistent blackish stem remained. In addition, mats of rotting *Zannichellia* were present through all the lakes as a consequence of dispersion by wind. Seeds were present in this material and presumably were being shed so that the species is probably now more widely dispersed in the Apollo Lake system than was the case a year ago.

Although there is no mention in the literature of a second autumnal burst of growth in development in Zannichellia, extensive seed germination and the origin of new shoots from the prostrate rhizome system was noted in early October. The presence of a substrate is required for seedlings to become established and the number of germinating seeds which had failed to root was producing a considerable windrow along the edges of all three lakes. Attached seeds were noted along the entire margin in about 6 inches of water and extensive development of new upright shoots from the persistent rhizome was also observed.

The photographs in Figure 52 show some of the aesthetic objections to the plant and filamentous algae growths. Figure 52C is a photograph of the Zannichellia growing in Lake No. 3 in July, 1973. Figure 52-B is another photo of Lake No. 3, but taken in September, 1973. By that time, as the photo shows, large mats of filamentous algae were visible in the water surface but most of the Zannichellia had died away. Figure 52-A was taken in October, 1973, after an autumnal bloom of the Zannichellia had occurred, and this photo shows an interwoven mat of algae and Zannichellia.

Almost all of the filamentous algae and Zannichellia plant growth took place in Lake No. 3. The reason for this was that Lake No. 3 has more wind-protected areas than the other two lakes, and because much of it is 1 to 2 feet, on the average, shallower than the other lakes. Figure 49 is a map of the lakes showing the places where most the growth occurred. The relationship of the plant and algae growth to wind protection and depth of water can be seen plainly in this figure.



A. Interwoven mat of _Zannichellia_ and Filamentous Algae
B. Filamentous Algae Mats
C. _Zannichellia_ Growth

Figure 52 FILAMENTOUS ALGAE AND AQUATIC PLANT GROWTHS

These lakes are in a very windy area. Nearly every afternoon is windy, and wind velocities over 40 mph are not uncommon. For example, the climatological records maintained at the County General William J. Fox Airfield, which adjoins these lakes, show for June of 1973 the wind on every day reached at least 15 mps, and winds of 30 mph or more occurred on 15 days. Because of these winds the wave action in these lakes is substantial.

This wind and wave activity breaks up and uproots any Zannichellia or filamentous algae blooms trying to grow in the more open lake areas. Also the currents developed by these winds and waves helps to concentrate these growths by transporting the fragments to stiller areas.

Environmental Effects on Phytoplankton

Two environmental factors that are usually very important to algae growth are temperature and sunlight. To help examine how these factors affect algae, Figures 53 and 54 have been drawn.

Temperature - Figure 53 shows a comparison between the average monthly water temperature (as measured at about 9:00 a.m.), and the cell count for phytoplanktonic algae. As this figure shows, the maximum algae populations occur in the summer months with the warmer water temperatures. However, significant blooms can also occur in winter and mid-spring months, as the average cell counts for January, 1972, April, 1971, and April, 1972 show. The predominating types of algae also vary from month to month, and the water temperatures may partly affect this. Table 22 shows the predominant algae and monthly water temperature for that month. In the cooler months, with water temperatures less than 10°C (50°F), the predominant algae types narrow down to mainly Chlorella and Chylamydomonas. To a less marked degree, this is also true for water temperatures in the

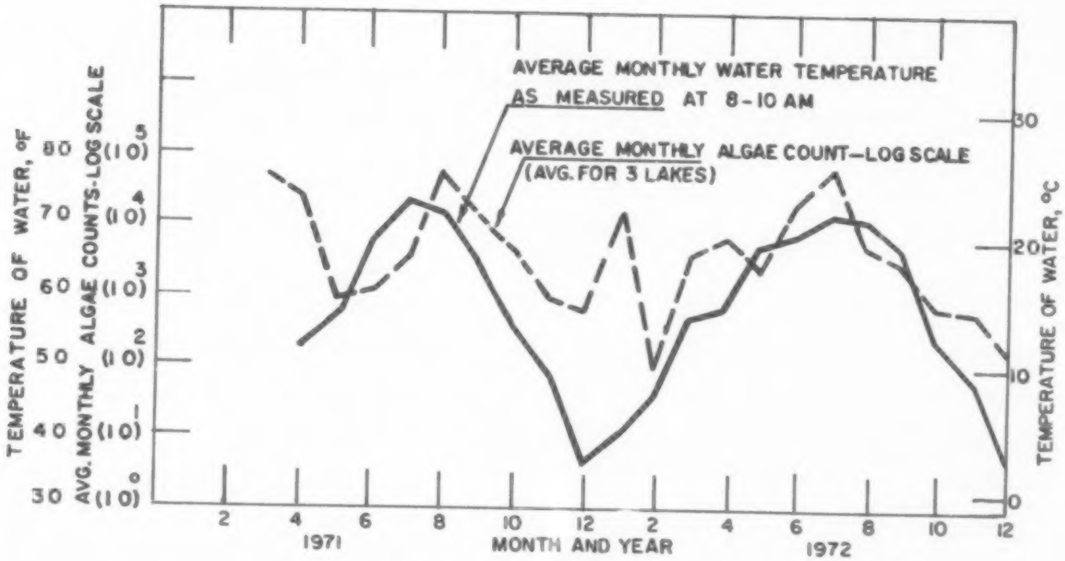


Figure 53 COMPARISON OF WATER TEMPERATURES AND ALGAE COUNTS IN LAKES

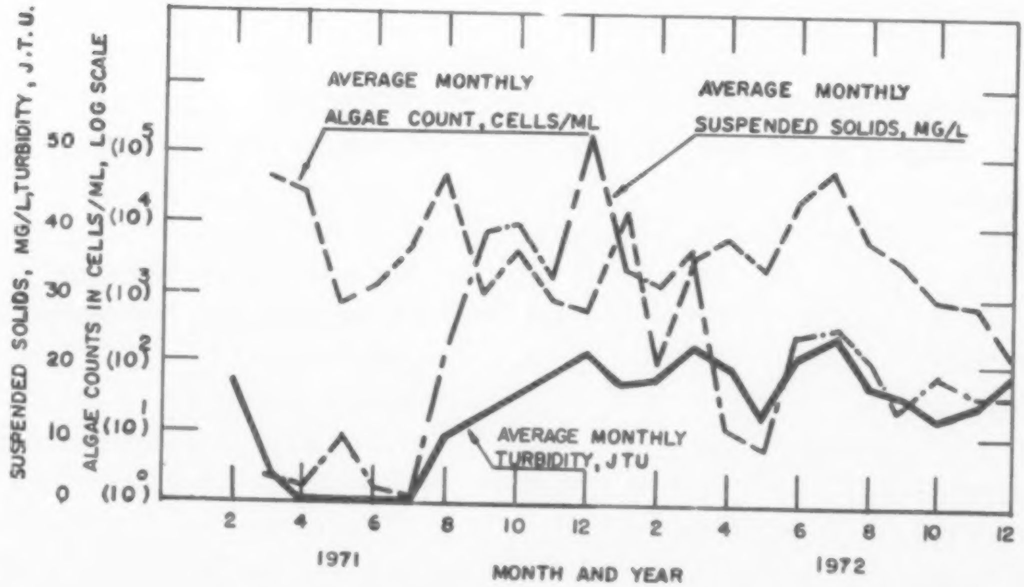


Figure 54 COMPARISON OF ALGAE COUNTS, SUSPENDED SOLIDS, AND TURBIDITY

Table 22 PREDOMINANT ALGAL TYPES RELATED TO MONTH AND AVERAGE WATER TEMPERATURES

Month	Average Water Temperature °C	°F	Predominant Algal Type
March, 1971	11.4	52.5	Chlamydomonas
April	12	53.5	Chlamydomonas, Chlorella
May	15	57.8	Chlorella, Nitzchia
June	21	70.0	Nitzchia
July	23	73.4	Chlorella, Chlamydomonas
August	22	72.1	Westella
September	18	64.4	Chlorella
October	13	55.1	Chlamydomonas, Chlorella
November	9	47.3	Chlorel
December	3	36.4	Chlorella, Coelastrum, Chlamydomonas
January, 1972	5	40.9	Chlamydomonas
February	8	46.5	Chlamydomonas
March	13.5	56.3	Coccoid
April	14	57.2	Coccoid
May	19	66.1	Coccoid, Chlamydomonas
June	21	69.3	Chlamydomonas, Oocystis
July	22	71.8	Oocystis
August	22	71.1	Chlorella
September	19	66.1	Scenedesmus, Schroderia
October	12	52.9	Chlorella
November	9	47.8	Chlorella
December	4	38.5	Chlorella

10-16°C (50-60°F range.) However, in the warmer months the variety of predominant algae is much wider, although Chlorella and Chylamydomonas may occur then also.

Sunlight - Sunlight also affects algae growth, as this supplies the energy for cell growth. The amount of turbidity and the concentration of suspended solids effect the amount of sunlight that can pass through the water. Thus some correlation between turbidity, suspended solids, and phytoplankton algae population ought to be expected. The cloudiness of the weather would also be a factor in this connection, but this was not measured in this study. Figure 54 shows a comparison between the average algae cell counts, the average monthly turbidity values, and suspended solids concentrations. No clear relationship between turbidity, suspended solids, and algae populations is apparent.

The relationship between turbidity and algae growth is examined more closely in Figure 55. Here the algae counts from the bottom of the lakes, which should show the most sensitivity to light reduction caused by turbidity are plotted along with turbidity. Again the data does not indicate that increases in turbidity cause reduction in algae populations.

Consequently, the clarity of the water, as indicated by suspended solids concentrations and turbidity, is not the controlling factor in causing algae blooms in this lake system.

Nutrients and Phytoplankton

The data was also examined for any relationships between phytoplankton algae population and nutrient levels in the water. Generally the most important nutrients are phosphorus and nitrogen. In this study these nutrients were measured as organic nitrogen, ammonia nitrogen, nitrates, nitrites, and total phosphates.

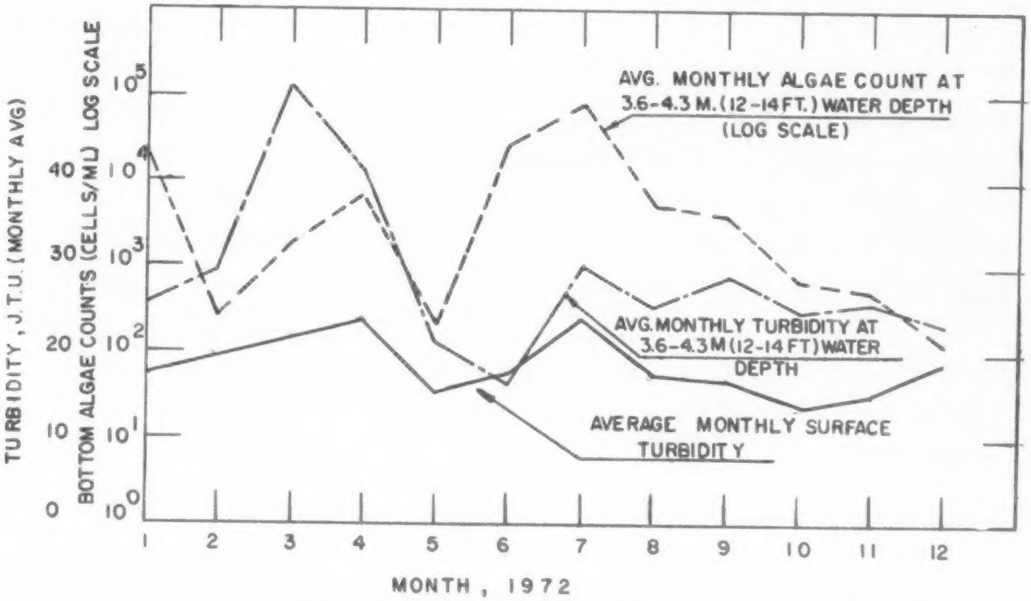


Figure 55 COMPARISON OF TURBIDITY AND ALGAE COUNTS AT 12-14 FT. WATER DEPTH

The concentration of a nutrient in a lake for any month is determined by:

1. The concentration of the previous month.
2. Any change in concentration due to replacement of the water with water of a higher or lower concentration.
3. The increase in concentration due to evaporation.
4. The increase in concentration due to nutrients carried in by irrigation runoff.

5. The increase in concentration due to a die-off of biota, partially releasing previously consumed nutrients.

6. The decrease in concentration due to consumption by biota within the lake.

Throughout the first six months of 1972, any possible inflow of nutrients due to irrigation runoff would have been negligible. This is because, as the hydrographs of Figure 56 show, very little irrigation was done until July of 1972. The major part of the irrigation water used before July was used on the Fox Airfield grounds, and none of this would have returned to the lakes.

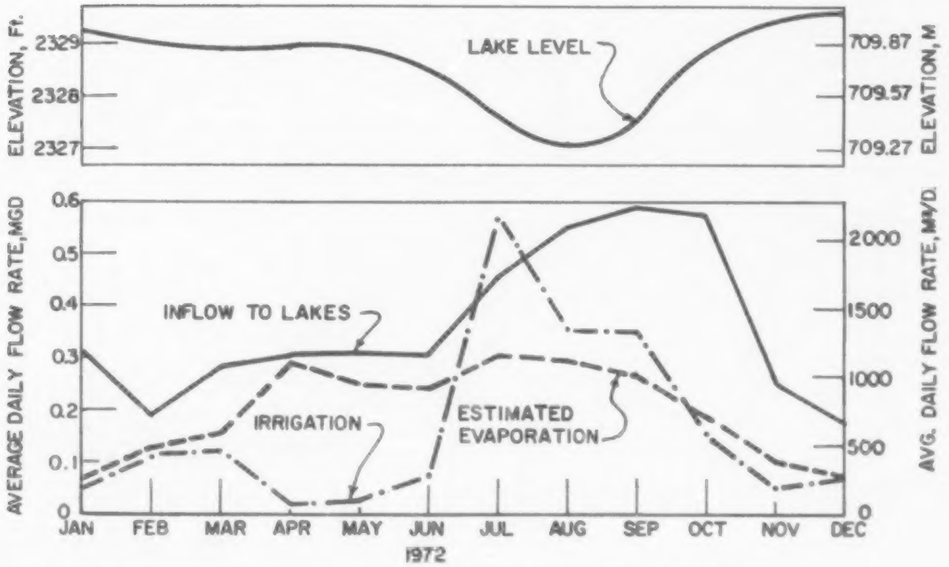


Figure 56 1972 HYDROGRAPHS FOR LAKES

Figure 57 shows a superimposed plot of algae population and nitrates for 1972. The nitrates are plotted separately for the tertiary plant effluent, and each of the individual lakes. The consumption of nitrates is shown in this graph by the decreasing concentrations of nitrates found in the waters as flow progresses through the lakes. For the first six months of 1972 the flow entered Lake No. 1 and irrigation water was pumped from Lake No. 3. During this period the nitrates are highest in Lake No. 1 and lowest in Lake No. 3.

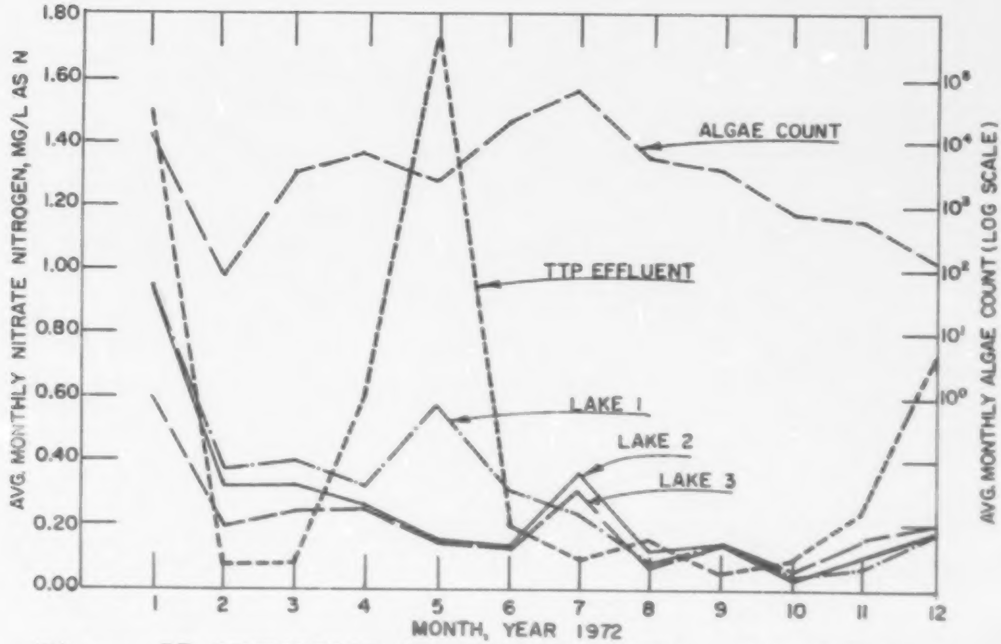


Figure 57 COMPARISON OF NITRATE LEVELS, INDIVIDUAL LAKES AND TERTIARY TREATMENT PLANT EFFLUENT

After June of 1972 the fresh tertiary influent was discharged into Lake No. 3 and the irrigation water was taken out of Lake No. 1. After a transition period the relative nitrate concentrations reversed, with the highest concentration in Lake No. 3 and the lowest in Lake No. 1.

If the nitrates were not being consumed the nitrate concentration in the first lake would be the lowest, and, principally due to evaporation, the concentration would steadily rise as the water progressed from lake to lake. As an example, such a rise due to evaporation is clearly seen in the graphs for total dissolved solids and alkalinity, Figures 58 and 59.

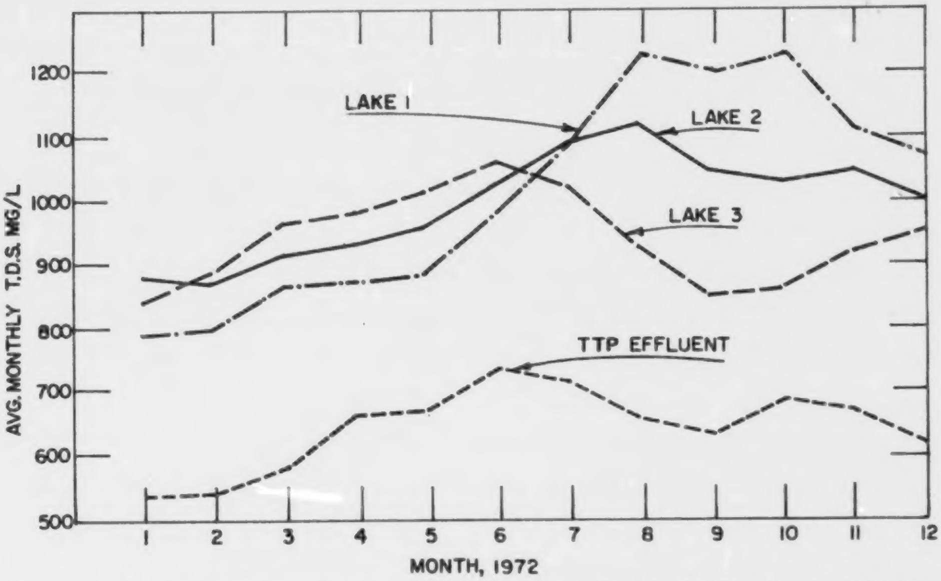


Figure 58 COMPARISON OF TOTAL DISSOLVED SOLIDS IN LAKES

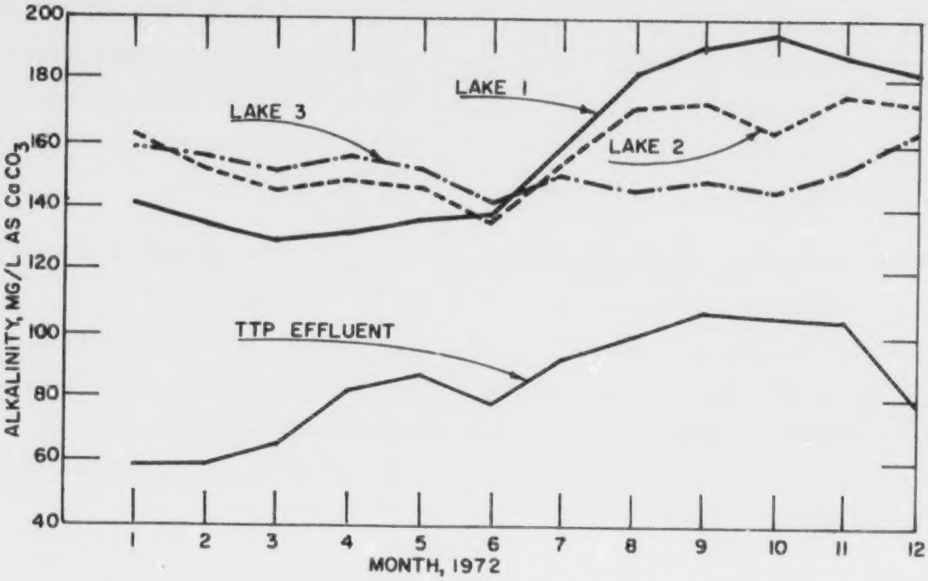


Figure 59 AVERAGE MONTHLY ALKALINITY LEVELS IN LAKES AND TERTIARY TREATMENT PLANT EFFLUENT

However, in the case of phosphates, organic nitrogen, and nitrites, the pattern is different. Comparison plots for these substances are shown in Figures 60, 61, and 62. For these nutrients the concentrations tend to increase as the water progresses from lake to lake. Thus the effect of consumption is less than the combined effects of evaporation and possible nutrient release. Ammonia nitrogen was also measured routinely, but a graph for this is not shown here. This is because the ammonia nitrogen levels were zero throughout almost all of 1972.

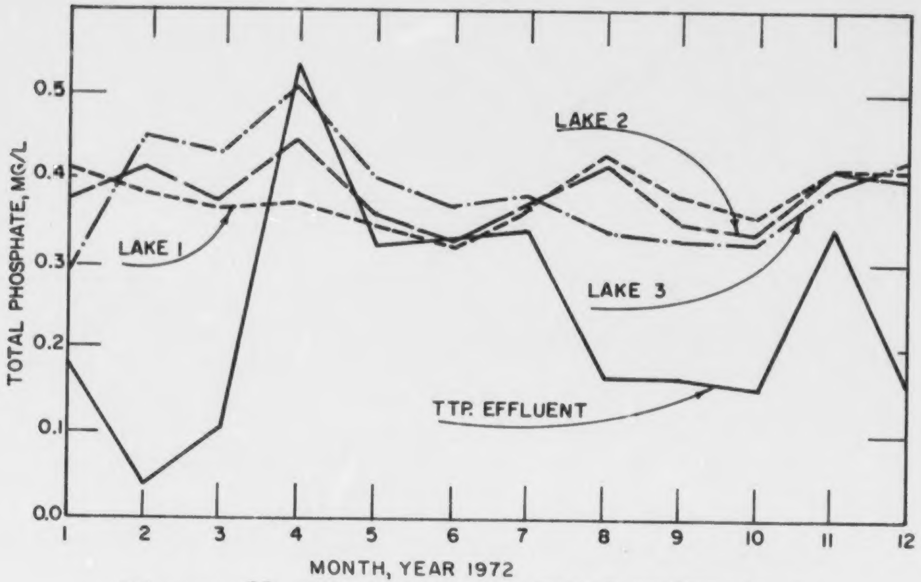


Figure 60 COMPARISON OF TOTAL PHOSPHATES, INDIVIDUAL LAKES AND TERTIARY PLANT EFFLUENT

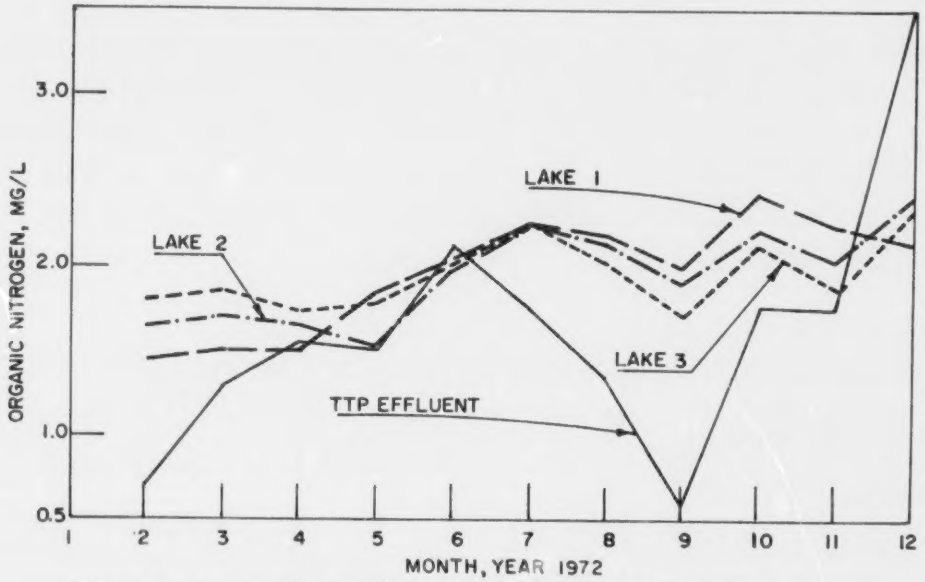


Figure 61 COMPARISON OF ORGANIC NITROGEN LEVELS, INDIVIDUAL LAKES AND TERTIARY TREATMENT PLANT EFFLUENT

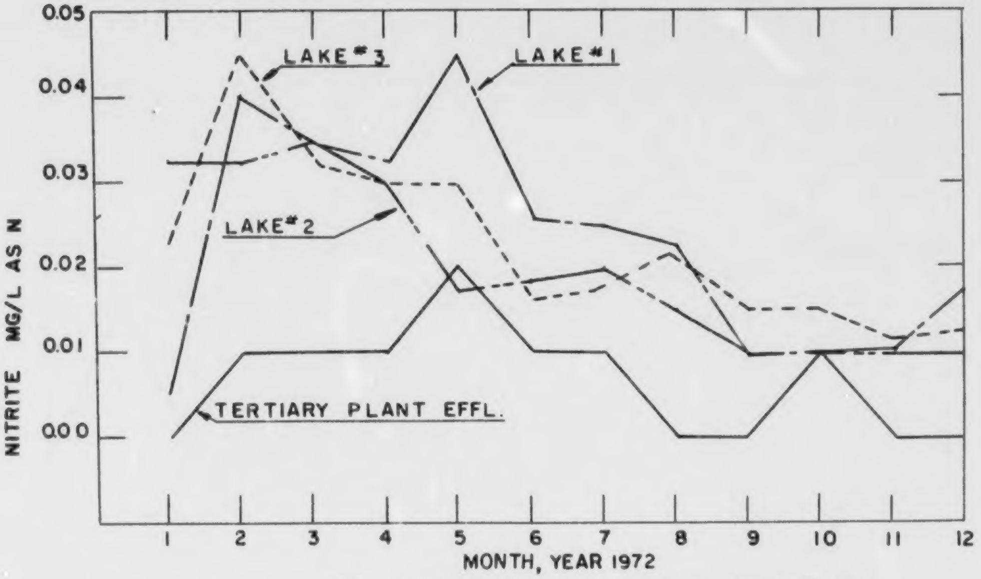


Figure 62 COMPARISON OF NITRITE LEVELS, INDIVIDUAL LAKES AND TERTIARY TREATMENT PLANT EFFLUENT

Because the influent and lake concentrations of nutrients, the influent hydrograph, and the irrigation hydrograph are known, the net nutrient consumption within the lakes can be computed by subtracting from the influent nutrients the nutrients removed by irrigation and any increases in the nutrients dissolved in the lake waters.

To calculate this on a monthly basis for example:

$$\left(Q_{inf} \cdot C\right) - \left(Q_{irrig} \cdot C'\right) - \left(V \Delta C'\right) = N.C.$$

where:

Q_{inf} = Total influent flow for the month, m^3

Q_{irrig} = Total irrigation outflow for the month, m^3

C = Average monthly concentration of nutrient (e.g., total phosphates, nitrates, organic nitrogen, etc.) in influent, as kg/m^3.

C' = Average monthly concentration of nutrient in lakes, as kg/m^3

V = Volume of water held in lakes, m^3

$\Delta C'$ = Change in nutrient concentration in lakes during month, kg/m^3

N.C. = Nutrient consumption by algae, aquatic plants, and other biota, kg/mo

The loss of a nutrient computed in this way would represent the quantity of that substance taken out of solution from the lakes and consumed by the algae, aquatic plants, or other biota in the lakes. A negative result obtained from the above computation would indicate a net release of that specific nutrient into solution. This could be caused by a die-off of the algae or aquatic plants that had previously consumed the nutrient.

Figure 63 shows the month by month computed consumption or release of total phosphates, nitrates, and organic nitrogen. These are the principal nutrients. Also plotted in Figure 63 is the average monthly algae count (phytoplankton).

The net nutrient release shown for June and July in Figure 63 may have been partially caused by fertilizers carried into the lakes by sprinkler irrigation runoff. The hydrograph of Figure 56 indicates that heavy irrigation began at that time. Prior to then this would not have been a factor, as very little irrigation was being done.

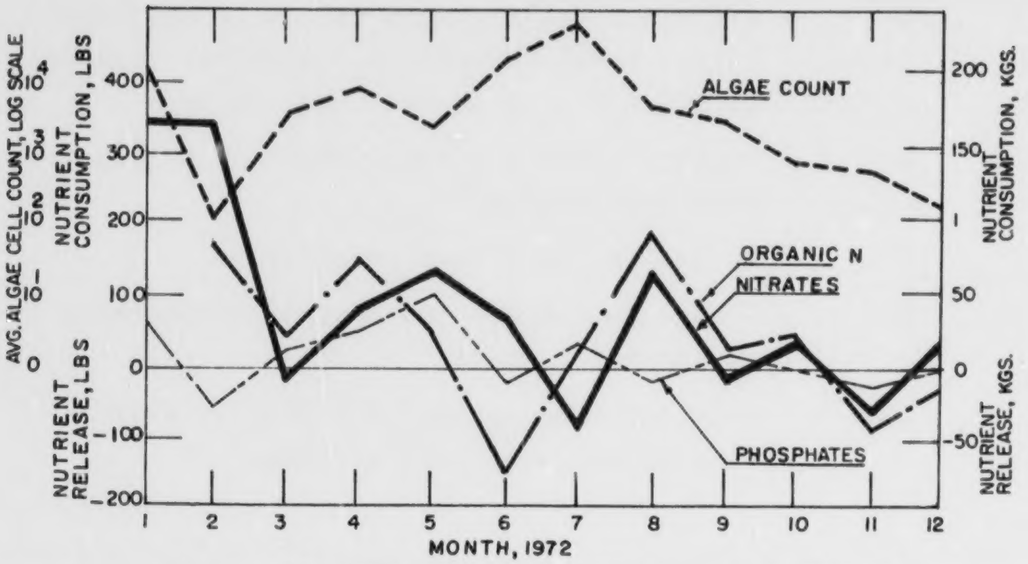


Figure 63 COMPARISON OF NUTRIENT CONSUMPTION AND ALGAE POPULATION IN LAKES

Because there is so little apparent correlation between the computed nutrient consumption or release and the algae population, the free swimming algae was not the principal consumer of these nutrients. Most of the nutrients were apparently consumed (or released) by other biota in these lakes, such as filamentous algae and aquatic plants.

Dissolved Oxygen

The effect of the algae on the dissolved oxygen (DO) levels was continually checked. A large algae population can cause severe diurnal fluctuation in DO, harming the fish. The DO was checked about an hour before dawn when the minimum should occur, then again in mid-morning when the regular water sample was taken. Figure 64 shows a plot of pre-dawn and regular daytime DO averages. Superimposed on this are the monthly average algae counts.

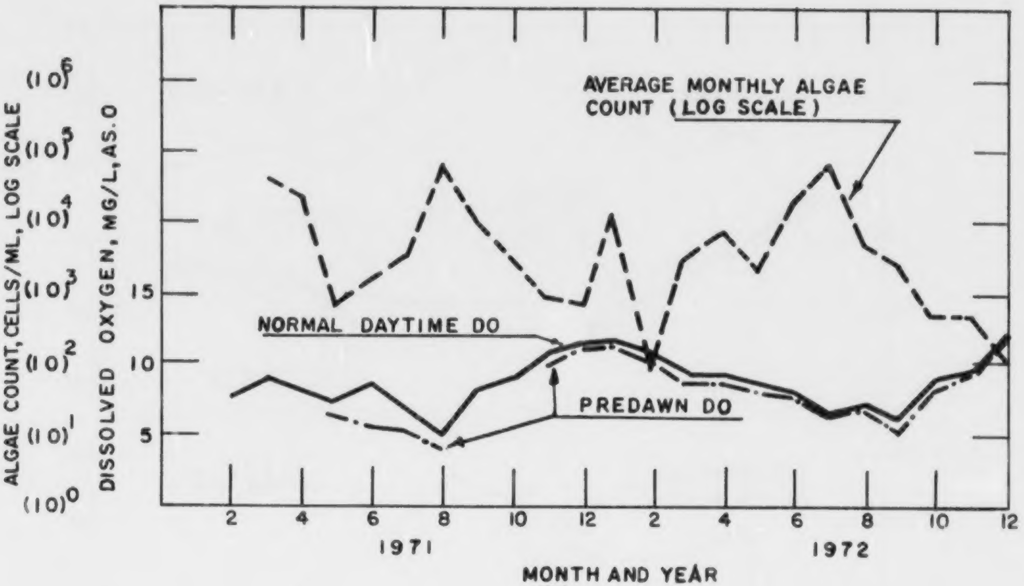


Figure 64

COMPARISON OF AVERAGE MONTHLY DO LEVELS AND
ALGAE COUNTS IN LAKES

The rise and fall of the DO averages is due primarily to water temperature. The algae populations do not, at the levels experienced, appear to seriously affect the DO levels or cause any wide differences between the pre-dawn and daytime DO level.

The profile chemical data collected included DO measurements. Figure 65 shows comparisons between the surface DO and the lake bottom DO and the corresponding algae counts for each lake. In Lake No. 2, Figure 65 shows a substantial difference in DO between the lake surface and bottom throughout the period of maximum algae growth.

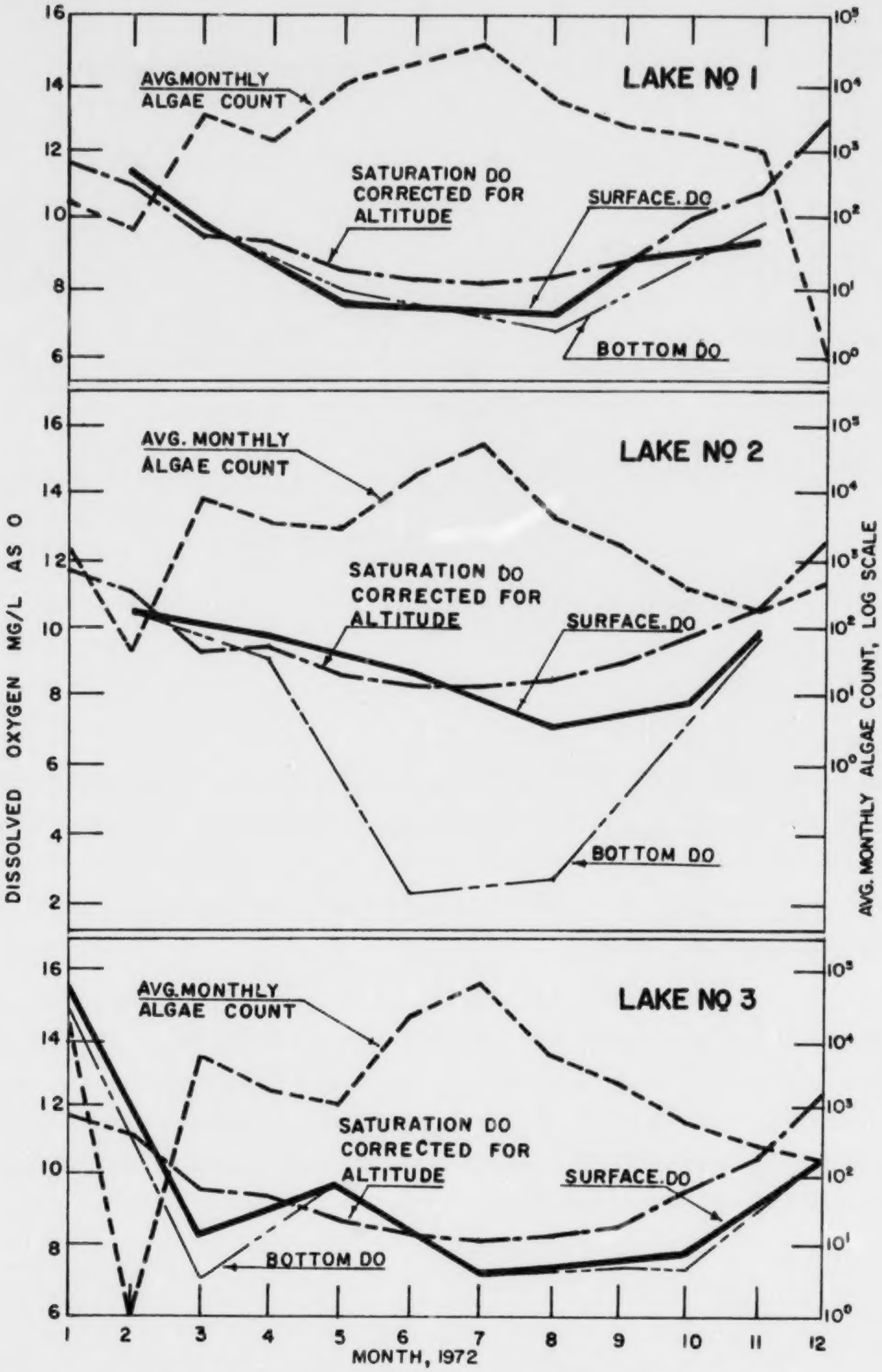


Figure 65 DISSOLVED OXYGEN AND
ALGAE COUNT LEVELS--LAKES 1, 2, and 3

While this may have been caused by the algae, the same effect does not occur in Lakes No. 3 and 1. The curves for surface DO are very similar for all three lakes.

The saturation values of dissolved oxygen, computed as a function of temperature, are also shown in Figure 65. The actual DO values generally run below the saturation value, particularly in the warmer months. However, the actual DO values shown here are somewhat biased in that all measurements were made between 8:00 and 10:00 a.m. They may not accurately represent the average that would have been obtained for measurements made over the entire day.

LABORATORY ALGAE NUTRIENT STUDIES

Introduction

Special laboratory scale algae nutrient studies were conducted by Dr. Jan Scherfig of the University of California, Irvine. The specific objectives of these studies were:

1. To identify factors responsible for algal growth in the recreational lakes:
    - (a) Growth limiting nutrients in,
        - (i) Tertiary treatment plant influent
        - (ii) Tertiary treatment plant effluent
        - (iii) Water in Lake No. 3
        - (iv) Water in Lake No. 2
        - (v) Water in Lake No. 1
    - (b) The role of trace metals and vitamins on the quality of the aquatic lake environment in relation to the performance of the tertiary treatment process.
2. To determine the reference level of algal growth in continuous culture under standard laboratory conditions for the five waters listed above.

3. To estimate the long-term steady state levels of algal and attached aquatic plant growth.

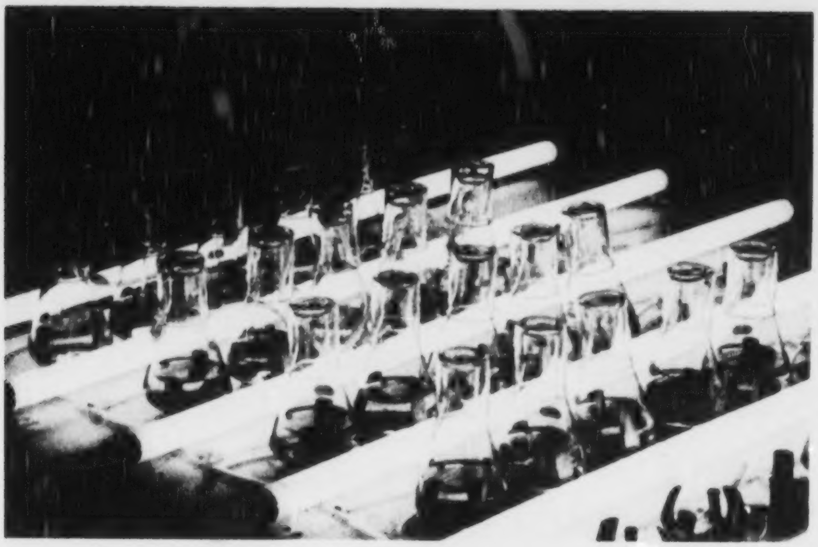
Two main types of laboratory experiments were conducted. These were: algal bioassay investigations (batch bioassays to determine the growth limiting nutrients or trace substances in the above waters), and continuous culture investigations. The continuous culture investigations were to evaluate the kinetic algal growth parameters and thus permit estimates of the reference algal growth levels for these lakes.

Water samples for these tests were collected from the tertiary plant and from Apollo Park Lakes in May, June, September and October, 1973. The long period over which samples were collected was designed to detect any difference in lake nutrient status due to the increasing photoperiod and seasonal variation. All water samples were collected in 19 liter (5-gallon) Nalgene bottles and stored in the dark at 4°C (39.2°F).

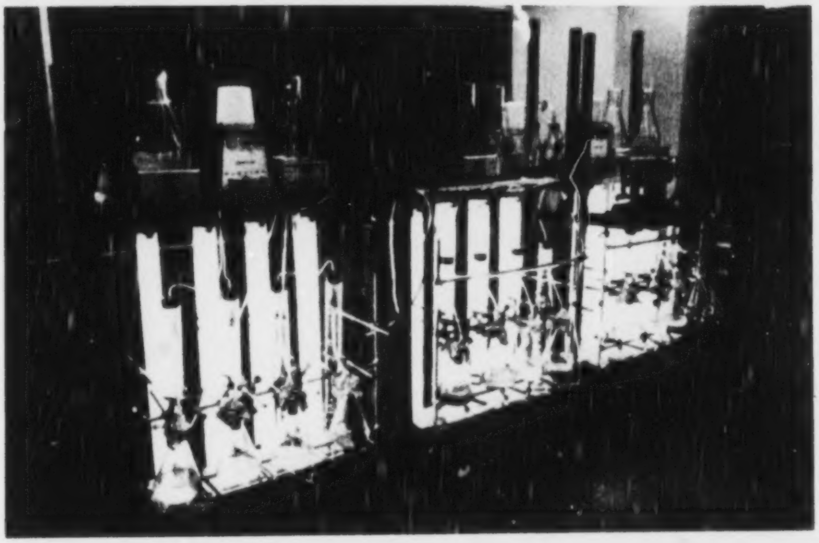
The samples were collected as grab samples from the tertiary plant influent (taken upstream to the alum injection point), plant effluent (downstream of the detention basin), and from the lakes. From each lake grab samples were taken from two standard locations.

Algal Bioassay Investigations

Batch algal assays were used to identify growth limiting nutrients. They were conducted in accordance with the "Algal Assay Procedure: Bottle Test."[25] All materials used in the culture apparatus were those shown to have minimal effect on algal growth (Justice, C., et al.[26]). A photograph of a typical batch assay unit is shown in Figure 66.



BATCH ALGAL BIOASSAY UNIT



CONTINUOUS CULTURE UNIT

FIGURE 66 PHOTOGRAPHS OF LABORATORY EQUIPMENT USED IN ALGAE NUTRIENT STUDIES

Selenastrum Capricornutum Printz, as recommended in "Algal Assay Procedure,"[25] was used throughout this investigation as the test species. Stock cultures were plated several times to minimize bacterial contamination and maintained at 20°C (68°F) in the standard nutrient medium.

The reference medium used for spiking purposes and as a standard against which the different effluents were compared is shown in Table 23. The reference medium was made up in batches from time to time during the course of an experiment and conforms to the recommendations of "Algal Assay Procedures."[25]

Growth limiting nutrients were determined by means of factorial spiking experiments as described by Murray et al.[27] and in "Algal Assay Procedures."[25] The factorial experiments were designed and analyzed as fractional factorials as described in Plan 6A.1 by Cochran and Cox.[28] "Factor" refers to the element (or combinations of elements added as a single factor) as shown for each experiment. Two sets of preliminary spiking experiments and two sets of factorial experiments were conducted for each of the five water samples. Since it had been agreed that vitamins would be one of the factors investigated in the factorial experiments some preliminary experimentation was necessary to determine how best to arrange the remaining nutrients into factors.

Nutrients investigated in the first preliminary experiments were classified in the following three groups:

1. phosphorus and nitrogen combined
2. iron and manganese combined
3. trace metals (B, Zn, Co, Cu, Mo)

Table 23 REFERENCE MEDIUM COMPOSITION

Macronutrients - The following salts, Biological or Reagent grade, in milligrams per liter (mg/l) of glass-distilled water.

Compound	Concentration (mg/l)	Element	Concentration (mg/l)
$NaNO_3$	25.500	N	4.200
K_2HPO_4	1.044	P	0.186
$MgCl_2$	5.700	Mg	2.904
$MgSO_4 \cdot 7H_2O$	14.700	S	1.911
$CaCl_2 \cdot 2H_2O$	4.410	C	2.143
$NaHCO_3$	15.000	Ca	1.202
		Na	11.001
		K	0.469

Micronutrients - The following salts, Biological or Reagent grade, in micrograms per liter (µg/l) of glass-distilled water.

Compound	Concentration (µg/l)	Element	Concentration (µg/l)
H_3BO_3	185.520	B	32.460
$MnCl_2$	264.264	Mn	115.374
$ZnCl_2$	32.709	Zn	15.691
$CoCl_2$	0.780	Co	0.354
$CuCl_2$	0.009	Cu	0.004
$Na_2MoO_4 \cdot 2H_2O$	7.260	Mo	2.878
$FeCl_3$	96.000	Fe	33.051
$Na_2EDTA \cdot 2H_2O$	300.000		

Nutrients selected for the second set of preliminary experiments were:

1. nitrogen
2. phosphorus
3. no addition

Data from the preliminary spiking experiments were used to select three other factors which would be tested with the vitamin factor in the growth limiting factorial experiments. Factors selected were:

1. nitrogen
2. phosphorus
3. trace metals (B, Zn, Co, Cu, Mo, Fe, Mn)
4. vitamins (thiamine, biotin and B-12)

Spiking was performed by the addition of specified amounts of concentrated stock solutions of nutrients such that the increase in concentration after addition to the sample being tested corresponded to 33 percent of the concentration of the reference medium described above. For example, spiking with iron was done such that 11 µg Fe was added per liter of sample being tested.

Two different parameters of biomass were used to measure algal growth: cell number and total cell volume. The methods used to determine these parameters are described in detail by Murray et al.[27]

The different ways of measuring algal growth are useful for different types of investigation. Measurement of dry weight is useful in terms of energy values, cell numbers are of significance from a turbidity and analytical point of view, and total cell volume is a useful parameter which may combine the advantages of cell counts and dry weights.

Table 24
VITAMIN ANALYSES OF LAKE WATER SAMPLES

Lake No.	Date Collected	Thiamine (HCL) µg/l	Vitamin B-12 µg/l	Biotin µg/l
1	5-9-73	<0.02	0.016	0.009
1	9-5-73	0.8	0.031	0.020
2	5-9-73	<0.02	0.023	0.013
2	9-5-73	0.30	0.053	0.020
3	5-9-73	<0.02	0.12	0.017
3	9-5-73	0.60	0.039	≤0.010

Measurements of cell volume correlate best with optical density, what the eye actually sees, and this may be the most useful assessment of algal growth, particularly by the nontechnical viewer.

In order to furnish supporting information for these laboratory tests, chemical analyses were made for each sample. Each sample was analyzed for the following parameters: suspended solids, dissolved solids, volatile suspended solids, volatile dissolved solids, nitrates, nitrites, Kjeldahl nitrogen, total phosphate, ortho phosphate, iron, manganese and pH. In addition, some of the lake samples were analyzed for thiamine, vitamin B12 and biotin as shown in Table 24. A semiquantitative spectrographic analysis was performed on each of the five water samples collected in September and also on the reference medium. The results of these chemical analyses are summarized in Tables 24, 25, and 26. Chemical analyses were conducted in accordance with "Standard Methods for the Examination of Water and Waste Water"[6].

Table 25

ANALYSIS OF WATER SAMPLES FOR LABORATORY STUDIES

Constituent*	Sampling Date (1973)	Tertiary Influent	Tertiary Effluent	Lake 1	Lake 2	Lake 3
Suspended Solids	9 May	113	4	60	50	27
	18 June	117	5	67	41	36
	5 Sept	118	1	39	27	28
Dissolved Solids	9 May	660	657	1101	1031	942
	18 June	686	642	1158	1075	924
	5 Sept	706	758	1198	1149	1055
Volatile Suspended Solids	9 May	106	4	12	12	8
	18 June	109	5	18	8	16
	5 Sept	50	0	6	6	7
Nitrate Nitrogen (as N)	9 May	1.7	1.9	.2	.2	.6
	18 June	.1	.1	.1	.1	.1
	5 Sept	.01	.00	.02	.01	.02
Nitrite Nitrogen (as N)	9 May	.38	.01	.02	.02	.02
	18 June	.03	.02	.03	.00	.00
	5 Sept	.01	.00	.02	.01	.02
Kjeldahl Nitrogen (as N)	9 May	12.0	2.1	2.8	2.5	2.2
	18 June	15.4	2.1	2.4	2.1	2.1
	5 Sept	13.4	2.4	2.5	2.5	2.8

*NOTE: All units are in mg/l unless otherwise shown.

Table 25 Cont'd

ANALYSIS OF WATER SAMPLES FOR LABORATORY STUDIES

Constituent*	Sampling Date (1973)	Tertiary Influent	Tertiary Effluent	Lake 1	Lake 2	Lake 3
Total Phosphate	9 May	24.3	.48	.87	1.02	4.19
	18 June	31.0	.10	.38	.29	.21
	5 Sept	24.1	.16	.49	.53	.40
Ortho-Phosphate	9 May	23.2	.13	.44	.35	.40
	18 June	19.4	.06	.35	.26	.19
	5 Sept	23.5	.09	.33	.31	.27
Iron	9 May	.15	.14	4.00	3.30	2.30
	18 June	1.05	.60	4.85	2.20	2.35
	5 Sept	.06	.02	2.85	1.95	1.38
Manganese	9 May	.01	.01	.07	.05	.04
	18 June	.02	.01	.09	.07	.04
	5 Sept	.02	.02	.05	.04	.04
Volatile Dissolved Solids	9 May	161	55	31	47	80
	18 June	117	49	69	84	58
pH (pH units)	18 June	8.97	6.58	8.73	8.77	8.87
	5 Sept	9.08	6.82	8.35	8.52	8.22

*NOTE: All units are in mg/l unless otherwise shown.

Table 26

SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSIS OF METAL CONTENT IN WATER SAMPLES

NOTE: Values shown are expressed as percent of inorganic fraction of dissolved solids.

Element	Tertiary Influent	Tertiary Effluent	Lake 1	Lake 2	Lake 3	NAAM
Na	26.1	28.0	25.3	26.4	28.4	17.8
K	3.1	3.2	2.4	2.8	2.8	1.5
Ca	.86	.80	2.4	1.2	.58	.45
Si	2.6	.72	2.3	1.6	.92	.16
Mg	.55	.60	.62	.64	.36	7.0
Al	.01	.0062	.21	.15	.056	.0018
B	.042	.022	.031	.16	.20	.27
P	1.5	.74	.41	.36	.42	
Fe	.02	.0035	.15	.15	.10	
Mn	.0016	.0016	.0049	.0032	.0023	.086
Pb	.065	.053	.037	.0073	.0083	.86
Mo	.034	.0034	.0042	.0026	.0017	.027
Li	.006	.0044	.0024	.0022	.0025	.014
Cu	.0011	.0004	.075	.0015	.0028	
Ti	.0033	.0029	.012	.0073	.0017	.029
Sr	.050	.044	.063	.06	.047	
Cr	.0015	.0028	.0022	.0016	.0015	
Ag			.0002	.0002	.0003	.0031
Co						.0010
Ni						.0036
Other	Nil	Nil	Nil	Nil	Nil	.0020 Nil

Results of Preliminary Spiking Experiments

Treatment plant and lake water samples collected in May and June were evaluated in a two-step procedure.

The first step, using the May water samples, was to compare these with the nutrients in the reference medium, excluding macronutrients such as calcium, magnesium, and sodium. The macronutrients were excluded because their concentrations are sufficiently high in treatment plant and lake waters to prevent them from being limiting.

Three replicates of each sample were sterilized and seeded with the test alga to an initial cell concentration of 10^3 cells per milliliter. After 13 days following seeding, which was approximately when the stationary phase of the growth curve was reached, each replicate was spiked with one of the three nutrients groups described above. Results of this spiking are shown in Tables 27 and 28. Spiking with the nitrogen-phosphorus combination resulted in a marked increase in cell numbers and total cell volume for the tertiary effluent and all lake water samples. A slight increase in total cell volume occurred in the tertiary influent samples spiked with micronutrients and the iron-manganese combination. Lake No. 3 water samples spiked with micronutrients showed a slow but definite increase in both cell numbers and cell volumes.

The second step in the preliminary investigation involved the evaluation of nitrogen and phosphorus separately. Three replicates of each of the June water samples were sterilized and seeded with the test alga to an initial concentration of 10^3 cells per milliliter. When stationary growth phase was reached, one replicate of each sample was spiked with nitrogen and one with phosphorus. The third, unspiked, replicate was used as a control for comparing total biomass produced.

Table 27

CELL VOLUME GROWTH, PRELIMINARY SPIKING EXPERIMENT

Day of Growth After Seeding

Sample Source	3	5	11	13	Spike	14	17	24
	Total Cell Volume 10^8 u^3/liter							
Tertiary Plant Influent	597	1650	5601	6340	(Fe + Mn)	7085	8076	7518
	499	1229	5139	6067	(N + P)	7171	7420	7618
	564	1474	5174	6461	(Micro)	6845	8065	7547
Tertiary Plant Effluent	144	422	506	559	(N + P)	821	1573	1961
	196	378	409	461	(Micro)	494	616	470
	129	373	387	437	(Fe + Mn)	449	476	395
Lake 1	273	249	198	350	(N + P)	341	1240	1865
	304	187	187	216	(Micro)	197	211	235
	145	262	184	221	(Fe + Mn)	262	198	227
Lake 2	235	300	227	326	(N + P)	312	1188	1915
	173	204	213	266	(Micro)	247	281	475
	446	162	169	226	(Fe + Mn)	254	315	315
Lake 3	174	228	471	545	(N + P)	754	1323	2234
	252	421	629	751	(Micro)	766	845	1319
	114	179	488	578	(Fe + Mn)	622	658	626

Table 28

CELL NUMBER GROWTH, PRELIMINARY SPIKING EXPERIMENT

Day of Growth After Seeding

Sample Source	3	5	11	13	Spike	14	17	24
	Cell Numbers as 10^7 cells/liter							
Tertiary Plant Influent	56	248	932	1177	(Fe + Mn)	1300	1464	1336
	45	172	890	1198	(N + P)	1337	1513	1424
	48	241	847	1127	(Micro)	1212	1302	1264
Tertiary Plant Effluent	21	71	56	59	(N + P)	67	151	172
	26	49	46	47	(Micro)	52	56	50
	13	46	44	48	(Fe + Mn)	50	52	47
Lake 1	95	66	37	45	(N + P)	52	240	364
	132	46	41	31	(Micro)	33	35	36
	27	40	31	31	(Fe + Mn)	35	31	34
Lake 2	88	98	44	36	(N + P)	45	210	318
	57	60	41	34	(Micro)	32	39	56
	70	31	25	22	(Fe + Mn)	24	29	36
Lake 3	57	40	39	50	(N + P)	59	106	166
	61	65	79	84	(Micro)	89	93	130
	12	16	67	73	(Fe + Mn)	73	79	76

Results are shown in Table 29. Tertiary influent flasks spiked with nitrogen showed a 38% increase in cell numbers and a 28% increase in cell volumes indicating that, of the factors tested, nitrogen is limiting. Tertiary effluent was definitely phosphorus limited in this experiment, but complex interactions with nitrogen were observed in the main experiment which was designed to detect such differences. The results for the lake water samples collected for this experiment did not show a consistent effect of addition of the two nutrients tested. No reason was found for this inconsistency, and the same inconsistency was not repeated in the main spiking experiments, as more replicates were used.

Results of Main Spiking Experiments

The main batch experiments to determine limiting nutrients were performed as factorial experiments on the June 18 water samples.

Factorial experiments are designed to detect and evaluate differences between effects due to different treatment. In this case the objective is to detect differences in the magnitude of algal growth (effects) due to the addition of various factors (treatments) to the water sample being tested. Each treatment must have at least two replicates in order to calculate the inherent or random experimental error. These experiments were designed and analyzed as 2^4 (four treatments each at two levels, with spike = level 1; without spike = level 0) partial factorials with two replicates for each treatment.

The partial factorial design reduces the number of flasks required for an analysis and permits the simultaneous assay of all five water samples at one time. This was considered important in assuring no difference due to sample storage or environmental conditions during the experiment. The

Table 29 ALGAL GROWTH FOR NITROGEN AND PHOSPHORUS SPIKING, PRELIMINARY SPIKING EXPERIMENT

Sample Source	Type of Spike	7 Days After Seeding		14 Days After Seeding		19 Days After Seeding	
		Cell Number*	Cell Volume**	Cell Number	Cell Volume	Cell Number	Cell Volume
Tertiary Plant Influent	None	122	2267	1002	5813	1103	6700
	N	483	3372	1408	7914	1522	8555
	P	640	3837	1025	5518	1116	6330
Tertiary Plant Effluent	None	30.5	267	27.4	255	31.0	279
	N	25.4	213	21.2	202	24.9	230
	P	68.0	499	75.7	646	83.5	737
Lake 1	None	11.9	83.2	19.5	126	34.6	290
	N	38.7	212.0	29.6	257	33.4	275
	P	5.9	41.3	21.0	116	22.2	159
Lake 2	None	20.4	130	31.3	223	41.2	222
	N	44.0	220	47.6	221	26.0	132
	P	23.8	125	42.7	177	43.9	194
Lake 3	None	27.2	145	70.6	408	36.3	312
	N	10.0	125	30.0	205	26.9	209
	P	No data	No data	52.4	245	46.7	251

NOTES *Cell Number = Number of cells at 10^7 cells/liter

**Cell Volume = Cell Volume as 10^8 u^3/liter

The spike was added on the 13th day after seeding.

specific experimental design used in this case allows for separation and analysis of the four main effects: nitrogen, phosphorus, trace metals and vitamins, but does not allow for separation of all interactions between the main effects.

Using such a design, which has a total of 16 flasks for each experiment, significance levels for the four main factors and three first-order interactions can be determined. Duplicate flasks were spiked with the appropriate nutrients as described previously. Algal growth was monitored every few days until maximum growth was achieved. Maximum growth for cell number and total cell volume might occur on different days if cells continue to enlarge but do not divide. Data from the day of maximum growth was analyzed for significant factors.

As in the preliminary spiking experiments, a statistical analysis of the results of this main spiking experiment showed that trace metals and the vitamins mentioned above were not significant limiting factors for algal growth.

Because trace metals and the specified test vitamins were eliminated as growth limiting factors, the data from the main spiking experiment were analyzed to examine the effect of the two principal nutrients, nitrogen and phosphorus. This was done by grouping the 16 individual results in each experiment into 4 groups of 4 flasks each, as follows:

Group I - No N or P spike
Group II - N spike added
Group III - P spike added
Group IV - Both N and P spike added

The average results of the flasks in each group were then calculated, and are shown in Table 30. The increases in the

Table 30 SUMMARY OF SIGNIFICANT NUTRIENTS AFFECTING ALGAL GROWTH

Values in table indicate average growth and difference between no treatment and spiking with nitrogen, phosphorus, or nitrogen and phosphorus combined.

Sample	Growth Parameter	Group I No Addition Average	Group II N Added Average-Increase		Group III P Added Average-Increase		Group IV N & P.Added Average-Incr.	
Tertiary Influent	Cell No.	684	851	67*	690	6	820	136
	Cell Vol.	4527	5489	967*	4425	-102	5245	718
Tertiary Effluent	Cell No.	103	97	-6	106	3	241	138*
	Cell Vol.	684	977	296*	694	13	1873	1192*
Lake #1	Cell No.	67	183	116*	67	0	304	237*
	Cell Vol.	389	1661	1272*	411	22	2106	1717*
Lake #2	Cell No.	62	139	77*	60	-2	311	249*
	Cell Vol.	360	1258	898*	359	-1	2141	1781*
Lake #3	Cell No.	71	101	30*	70	-1	272	201*
	Cell Vol.	410	1023	613*	413	3	2116	1706*

*Indicates statistical significance

different growth parameters are as a result of spiking.

Results for the tertiary influent water sample show that nitrogen addition resulted in a slight but statistically significant increase in cell number, but not in total cell volume. Thus, it can be concluded that the influent to the tertiary plant, although slightly nitrogen limited, is actually a fairly balanced medium for algal growth.

The analysis of the data for the tertiary plant effluent shows very clearly that nitrogen is limiting and that there is a highly significant interaction between nitrogen and phosphorus. A spiking with nitrogen alone results in an increase in cell number and cell volume, as compared to the average of the four unspiked flasks in Group I. A spiking with phosphorus alone does not result in a significant increase in algal growth. However, if a combined nitrogen and phosphorus spike is added, the resulting growth is higher than that observed for nitrogen alone.

Based on these results it can be concluded that nitrogen is limiting in the tertiary effluent but that nitrogen and phosphorus are quite closely balanced. In fact if the nitrogen concentration in the effluent increased by a small amount then phosphorus would have been limiting.

Identical conclusions can be made for the three lake water samples. Comparison of the growth increases from nitrogen spiking show that the smallest increase is found in the tertiary effluent and that the effect of spiking with nitrogen alone then increases from the tertiary effluent to Lake No. 3, to Lake No. 2, and is highest in Lake No. 1. The circulation of the lake water at the time the samples for these tests were taken was from the tertiary plant effluent to Lake No. 3 to Lake No. 2, to Lake No. 1. Water was drawn from Lake No. 1 for irrigation in the park.

The interpretation of this phenomena is that the tertiary effluent has the smallest amount of "unused" or biologically available phosphate and that the amount of "unused" phosphate increases through the lake system. This conclusion is substantiated by the chemical results presented in Table 25. There are two possible explanations for this, either that there is a source of nutrients (phosphate) into the lakes other than the tertiary effluent or that there is an evaporative concentration and biological modification of some of the insoluble phosphate in the tertiary effluent.

The results of the batch assays can be used to determine the biological availability of the non-ortho phosphate and Kjeldahl nitrogen. The general principles are based on the observed interactions and the alternating growth limitation of nitrogen and phosphorus in the spikings. The principles and methods are described in detail by Scherfig and Dixon[29].

Continuous Culture Investigations

Continuous culture investigations, using a chemostat, provide a means for evaluating various parameters relative to algal growth kinetics. From these evaluations, constants in the mathematical expressions describing algal growth in cultures receiving fresh medium can be determined. The theory behind the formulation of these mathematical models is discussed in detail in "Algal Assay Procedure: Bottle test"[25]. To analyze these growth parameters by continuous cultures, a system incorporating culture vessels with rates of fresh medium inflow equal to the outflow rate must be established. Ideally, with complete mixing, maintenance of constant volume, and uniform light and temperature regimes, a dynamic system should result in which the algal growth rate can be kept constant indefinitely. Because of the constant inflow rate of fresh nutrients, the biomass in the system should level off at a quantity which can be maintained by the concentration of nutrients in the inflow. At "steady state," measurements of various growth parameters permit application of theoretical models to the practical concerns of predicting algal growth rates in a particular body of water, given certain levels of nutrients and a characteristic residence time.

The generally accepted Monod mathematical model for describing the relationship between growth rate and nutrient concentration is based on the Michaelis-Mention equation which is given in "Algal Assay Procedure"[25].

$$\mu = \hat{\mu} \quad \frac{S}{K_s + S}$$

where μ = specific growth rate, time $^{-1}$
$\hat{\mu}$ = maximum specific growth rate, time $^{-1}$
S = Concentration of the growth rate limiting nutrient
K_s= half saturation constant
Y = gram cell produced/gram nutrient taken up by the cells

Solving for the reciprocal 1/u gives:

$$1/\mu = 1/\hat{\mu} + (K_s/\hat{u} \cdot 1/S)$$

which illustrates the linear relationship between $1/\mu$ and 1/S.

Thus, for a given concentration of rate limiting nutrient in a body of water under study, the theoretical specific growth rate can be predicated. Furthermore , if values for

S, μ, and the yield constant Y are known, then the mean cell concentration, X (standing stock), is determined by cellular residence time in the system because of the relationship (Pearson, et al.[30], 1971):

$$X = \frac{Y(S_o - S_1)}{\theta_u}$$

where θ = mean cellular residence time in the system
S_o = nutrient concentration in feed
S_1 = nutrient concentration in chemostat effluent

To generate data for determination of kinetic constants in the above growth equation and to determine the sustained level of algal growth in continuous culture conditions, chemostat experiments were conducted for each of the following sample media:

1. Tertiary influent
2. Tertiary effluent
3. Apollo Lakes,1, 2, 3
4. NAAM reference medium

The chemostat apparatus was assembled in accordance with Middlebrooks et al[31], using cylindrical, one liter, glass chambers with an air port near the bottom, an effluent approximately 10 cm. (4") from the top and nutrient feed lines entering the vessel through the rubber stopper at the top of the vessel. Mixing was provided by bubbling air mixed with CO_2 up through the vessels and by magnetic stirrers in the bottom of the vessel. All tubing, feed flasks and chemostats were sterlized by autoclaving at 121°C (250°F), 1.05 kg/cm^2 (15 PSI) for 15 minutes prior to assembly and use. Water samples taken on June 18, September 3, and October 7 were used successively throughout the experiment. Stored in plastic 19 liter (5 gallon) carboys at 4°C (39°F), samples were placed in acid-washed flasks and similarly sterilized prior to use. Constant illumination at 400 foot-candles was provided with cool-white fluorescent lamps. Temperatures were maintained within allowable ranges (see "Algal Assay Procedure"[25]), but problems with the CO_2 system resulted in occasional increases of pH in the chemostats.

Two replicate chemostats of each water source were run at three residence times approximating 8, 4, and 2 days. To determine the actual residence times the effluent volumes were weighed and measured periodically. This data was compared to the weight of fresh material pumped from the feed reservoirs to determine the magnitude of possible evaporation from either the feed or overflow flasks. The difference between any evaporation occuring from the feed flasks and that from the overflows was negligible.

Prior to activating the feed pumps, each chemostat was innoculated with 10^3 cells/ml and populations were allowed to increase for 3 days before input of additional nutrients. Cultures were run at steady state for approximately two to four residence times although assessment of steady state remained somewhat subjective because fluctuations in biomass parameters were believed to be associated with fluctuations in pH. Measurements of cell number and volume were conducted with a Coulter Counter, Model T, every other day for the 4 and 8-day residence time experiments and every day for the two-day residence time experiments. Dry weight biomass measurements were made several times during each experimental period. The details of the procedural techniques for determining these biomass parameters are discussed in Murray, et al.[27] Effluents from the chemostats were sampled near the end of the respective residence time periods for chemical analysis. Samples were filtered prior to analysis to remove those nutrients which had been converted to cellular material. Figure 66 shows the continuous culture apparatus used for these experiments.

Results - Nitrate and phosphate concentrations present during the growth experiments in each of the ten chemostats are shown in Table 31 for each of the three experimental periods. Data for biomass related parameters averaged over the steady state periods are summarized in Table 32. The values for all three lakes are lower than those for the tertiary influent and higher than those for the tertiary effluent. The level of algal growth in the tertiary effluent water (the influent to Lake No. 3) is much lower than the level of algal growth in the lake waters under the experimental conditions. This indicates the strong possibility of nutrient addition to the waters in the lakes after the tertiary treatment. The actual levels of algal growth in the lake waters were between five and twenty times higher than in the tertiary effluent entering the lakes, depending on the biomass parameters, lake, and residence time examined.

Efforts to determine detailed kinetic constants from the laboratory were not successful. There are three possible reasons for this. First, there were two simultaneous and interacting growth limiting nutrients (nitrogen and phosphorus), instead of only one as assumed in the growth model discussed above. Secondly, an unknown fraction of the Kjeldahl nitrogen and non-ortho phosphate is biologically available. The third and less important reason is that the concentrations of ortho phosphorus and nitrate nitrogen in the chemostats, S_1, were close to the minimum detectable value of the laboratory method available for determination. Thus, variations in S_1 due to the analytical method

Table 31 AVERAGE NUTRIENT CONCENTRATIONS IN CHEMOSTAT INFLUENT AND EFFLUENT

Nutrient	Lake 1	Lake 2	Lake 3
TOTAL PHOSPHATE (mg P/l)			
2 day			
Influent 10-2-73	0.15	0.18	0.14
Effluent 10-2-73	0.02	0.03	0.01
4 day			
Influent 9-5-73	0.05	0.07	0.07
Effluent 9-12-73	0.03	0.06	0.06
8 day			
Influent 11-18-73	0.13	0.16	0.06
Effluent 11-18-73	0.01	0.02	0.01
ORTHO PHOSPHATE (mg P/l)			
2 day			
Influent 10-2-73	0.09	0.09	0.08
Effluent 10-2-73	0.01	0.01	0.02
4 day			
Influent 9-5-73	0.05	0.12	0.05
Effluent 9-12-73	0.04	0.02	0.06
8 day			
Influent 11-18-73	0.09	0.12	0.08
Effluent 11-18-73	0.01	0.01	0.01
NITRATE (mg N/l)			
2 day			
Influent	2.20	1.82	1.08
Effluent 10-2-73	2.59	1.75	1.75
4 day			
Influent 9-5-73	2.89	4.20	2.23
Effluent 9-12-73	2.10	1.87	1.57
8 day			
Influent 11-18-73	1.68	1.62	1.79
Effluent 11-18-73	1.47	1.65	1.80

Table 31 Cont'd AVERAGE NUTRIENT CONCENTRATIONS IN CHEMOSTAT INFLUENT AND EFFLUENT

Nutrient	Tertiary Influent	Tertiary Effluent	Reference Medium NAAM
TOTAL PHOSPHATE (mg P/l)			
2 day			
Influent 10-2-73	10.56	0.08	-
Effluent 10-2-73	5.50	0.02	0.02
4 day			
Influent 9-5-73	8.90	0.07	0.14
Effluent 9-12-73	2.14	0.04	0.18
8 day			
Influent 11-18-73	2.57	0.07	0.28
Effluent 11-18-73	2.48	0.01	0.01
ORTHO PHOSPHATE (mg P/l)			
2 day			
Influent 10-2-73	6.00	0.06	-
Effluent 10-2-73	7.58	0.01	0.04
4 day			
Influent 9-5-73	9.70	0.05	0.19
Effluent 9-12-73	11.75	0.04	0.42
8 day			
Influent 11-18-73	5.87	0.06	0.27
Effluent 11-18-73	4.71	0.01	0.01
NITRATE (mg N/l)			
2 day			
Influent 10-2-73	0.84	1.06	-
Effluent 10-2-73	1.43	1.47	3.92
4 day			
Influent 9-5-73	1.92	1.65	3.95
Effluent 9-12-73	1.31	1.51	3.88
8 day			
Influent 11-18-73	1.19	1.18	5.32
Effluent 11-18-73	1.08	1.46	1.00

Table 32 CONTINUOUS CULTURE DATA SUMMARY

Sample Source	Average Residence Time (Days)	Cell Number (10^4 Cells/ml)	Dry Weight (mg/l)	Cell Volume (μ^3/l)
2-Day Residence Time:				
Tertiary Influent	2.1	231.0	136.0	1834
Tertiary Effluent	2.0	5.8	5.4	53
Lake 3	2.1	40.6	48.3	198
Lake 2	2.2	43.5	64.4	227
Lake 1	2.0	69.7	67.0	284
(Based on 8 days of data, averaged, including two biomass measurements and daily determinations of cell number and cell volume.)				
4-Day Residence Time:				
Tertiary Influent	3.0	339.3	162.0	2543
Tertiary Effluent	4.1	7.6	2.7	52
Lake 3	4.6	62.5	48.8	250
Lake 2	4.4	53.7	49.9	194
Lake 1	4.1	54.7	54.2	262
(Based on 11 days of data, averaged, including two biomass determinations and determinations of cell number and cell volume every two days.)				
8-Day Residence Time:				
Tertiary Influent	7.7	338.2	124.3	2113
Tertiary Effluent	7.6	11.6	1.3	100
Lake 3	7.9	31.1	30.4	223
Lake 2	8.5	38.6	63.9	268
Lake 1	8.9	36.6	53.4	199
(Based on 14 days of data, averaged, including three biomass determinations and determinations of cell number and cell volume every two days.)				

limitations might have made it impossible to obtain a straight-line plot of $1/\mu$ vs. $1/S_1$.

Evaluation

Despite the fact that kinetic constants could not be obtained, it is nevertheless possible to obtain significant information about waters in the lakes. Considering only the eight-day residence time, it can be seen from the data plotted in Figure 67 that the cell numbers in the chemostats for each of the three lakes are almost the same during the 14-day experimental period. From an algal growth promoting standpoint the waters in each of the three lakes are quite similar, a reflection on the fact that the waters for the three lakes have a common source.

With respect to the tertiary effluent, the difference between the batch results and the continuous culture results may be due to the different sample times. The batch samples and continuous culture samples were both collected at the same time in June. However, the chemostats did not stabilize and it was necessary to collect additional effluent and lake water samples in September and October.

Both the chemostat results and the chemical analyses for total phosphorus and nitrate plus Kjeldahl Nitrogen suggests that there are more nutrients in the lakes than in the tertiary effluent. If this is the case, there must be a nutrient input in addition to the input from the tertiary effluent.

It is not possible to pinpoint the precise geographical location of nutrient input to the lakes for two reasons. First, there could be considerable circulation occurring between the time algal nutrients entered the lakes and the time the waters were sampled for bioassay purposes. Second,

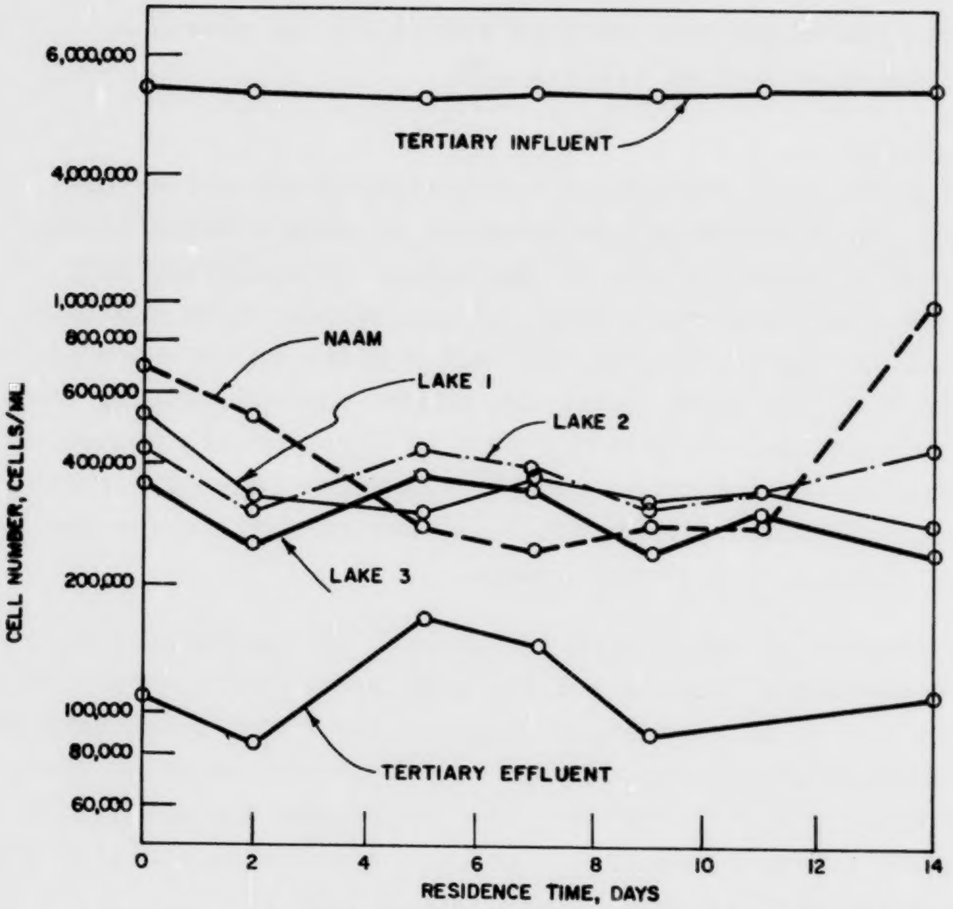


Figure 67 GRAPH OF CELL NUMBERS vs. RESIDENCE TIME

the nutrient input could well be distributed fairly uniformly so that no significant differences in the magnitude of enriched input would be detectable from one location to another. Finally as the data collected prior to June of

1972 shows, there is a definite increase in nutrient concentrations due to evaporation. As stated previously, it is obvious from these bioassay results that some sort of nutrient addition occurred in the lakes because of the consistent approximate 5-fold increase in cell numbers in the water of the three lakes.

The results also clearly show the effectiveness of the tertiary treatment process, by the approximate 30-fold reduction in cell numbers for the tertiary effluent over the tertiary influent.

From Table 31 it can be seen that the concentration of phosphate still available for algal growth is reduced to the greatest extent at the 8-day residence time. The nitrate data do not present such a clear pattern as the values are quite scattered.

In the tertiary plant influent, a large amount of phosphate remains available, relative to the other sample waters, even at the 8-day residence time. The nitrate data do not show a clear pattern. As discussed earlier, it will be necessary to determine the actual mechanism of the nitrate-phosphate interaction before definite conclusions can be made of the nitrate-phosphate data shown in Table 31. However, independent of the actual interaction mechanism, the results in Table 31 and 32 clearly show the quantitative effect of the tertiary treatment process and the subsequent nutrient augmentation occurring in the lakes.

Conclusions on Algal Growth

This study has assembled a great deal of information on phytoplankton growths within the Apollo Lakes, and upon the environmental conditions that would normally most importantly affect such growth. However, largely because of the effectiveness of the tertiary plant, objectionable phytoplankton growths were never a problem.

In the field data studies the phytoplankton showed very little response to environmental conditions or nutrients. Probably this is because phytoplankton populations were small and any relationships between them and environmental or nutrient conditions were overshadowed by the effect of aquatic plants and filamentous algae.

The laboratory studies showed that the principal growth limiting nutrient was nitrogen with a significant interaction between nitrogen and phosphorus.

Vitamins and trace metals were not growth limiting, as spiking with these substances caused no significant increased in cell volumes or numbers. Apparently, therefore, the lake waters contain more than enough of the tested trace metals and vitamins to support algae growth.

Both the field and laboratory studies demonstrated the marked effectiveness of the tertiary process in reducing algae regrowth potential. Although the plant had been designed on the basis of reducing algae regrowth by phosphate removal, both nitrogen and phosphorus are growth limiting nutrients in the tertiary plant effluent. As was pointed out in Section VII, the tertiary plant removes an average of 99% of total phosphates and 86% of organic nitrogen. Nitrates, nitrites, and ammonia nitrogen are not removed by the process.

Because nitrogen or a combination of nitrogen and phosphorus are the growth limiting nutrients, the prevention of irrigation runoff from entering the lakes is particularly important. Field observations, lake water analyses, and the chemostat tests have all indicated some nutrient augmentation due to runoff. Thus far, the results of this, in terms of aquatic plant or filamentous algae growth, has been low enough to be effectively controlled with a few manhours per month for mechanically removing and disposing of these growths. However, for the future, careful maintenance of the runoff protection berms will be required. Some parts of these have fallen into disrepair. Runoff interceptor berms may also need to be constructed.

CHEMICAL WATER QUALITY FACTORS

Regular measurements were made of the chemical constituents dissolved in the lake waters and tertiary plant effluent. This information is important in support of algae studies, for determine the suitability for irrigation, and for protection from health hazards.

Water Budget

Chemical water quality factors depend a great deal upon the water budget and the water use flowpath. The flow chart shown in Figure 68 shows how the tertiary plant effluent is routed through the lakes, and is lost either to evaporation or irrigation.

The flow values shown in Figure 68 are the mean design values as averaged over the whole year. The evaporation and irrigation outflow vary on a seasonal basis, being higher in the warmer months and lower in the cooler months. The inflow from the tertiary plant occasionally also varies, but this has no seasonal pattern.

As mentioned, the values shown in Figure 68 are the design values. The actual values obtained during the first full year of operation, 1972, are given in the hydrographs of Figure 56.

Some unknown fraction of the water used for park irrigation runs off and returns to the lakes. While the amount of

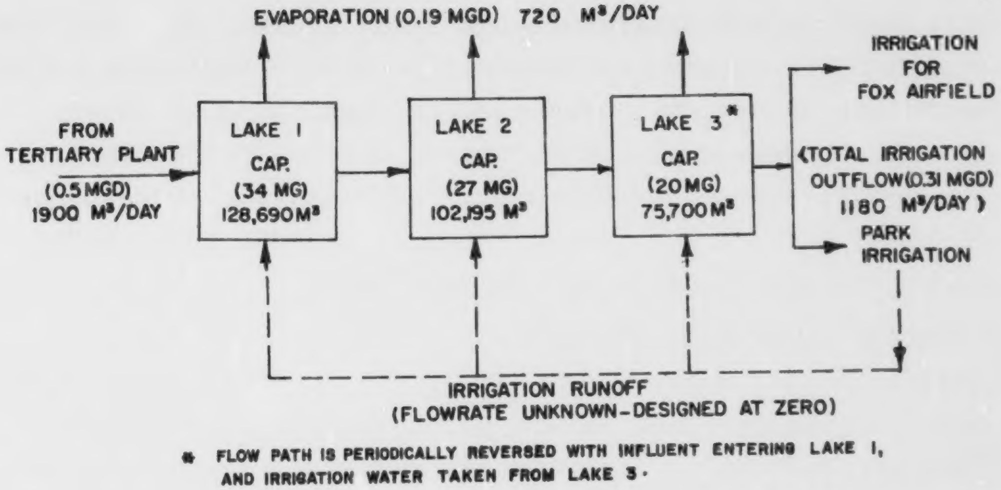

EVAPORATION (0.19 MGD) 720 M³/DAY
FROM TERTIARY PLANT
(0.5 MGD) 1900 M³/DAY
LAKE 1 CAP. (34 MG) 128,690 M³
LAKE 2 CAP. (27 MG) 102,195 M³
LAKE 3* CAP. (20 MG) 75,700 M³
IRRIGATION FOR FOX AIRFIELD
(TOTAL IRRIGATION OUTFLOW (0.31 MGD) 1180 M³/DAY)
PARK IRRIGATION
IRRIGATION RUNOFF (FLOWRATE UNKNOWN-DESIGNED AT ZERO)
* FLOW PATH IS PERIODICALLY REVERSED WITH INFLUENT ENTERING LAKE 1, AND IRRIGATION WATER TAKEN FROM LAKE 3.

Figure 68 WATER BUDGET FLOW DIAGRAM

water involved is unknown, it is probably slight in comparison to the total irrigation. Runoff interceptor berms had been constructed along the entire lake perimeter to prevent this water return, but these have been breached in places by erosion or damage by vehicles. Much of the park area slopes away from the lakes, and so runoff from those areas cannot enter the lakes. No irrigation water returns to the lakes via subsurface routes as the polyethylene lake lining prevents this.

The overall capacity of the lakes is 307,000 m^3 (81 million gallons). This gives a nominal average detention time for the incoming water of 162 days. The evaporation figure shown in Figure 56 is an estimate based on climatological records for the Lancaster area. This corresponds to an annual evaporation rate of 2.49 m/yr (98 in/yr).

Total Dissolved Solids

The concentration of total dissolved solids (TDS) in the lake waters was of particular interest. This is an important indicator of the suitability of the water for irrigation. Because part of the water is lost to evaporation, the average TDS level in the lakes (and, therefore, the TDS level of the water used for irrigation) should be higher than in the tertiary plant effluent. The concentration ratio (TDS conc. in lake effluent/TDS conc. in influent) should approach the value given by:

$$\frac{\text{lake influent}}{\text{irrigation outflow}} = \frac{1900\ \text{m}^3/\text{day}}{1180\ \text{m}^3/\text{day}} = \left(\frac{0.50\ \text{MGD}}{0.31\ \text{MGD}}\right) = 1.61$$

This concentration ratio is approximately what occurred. Figure 58 shows a plot of TDS vs. time for both the lake waters and the plant effluent. Averaged over nearly two years, the mean TDS level in the lakes was 912 mg/l, and in the plant effluent it was 620 mg/l. This gives an average concentration ratio of 1.47.

The TDS depends very greatly on the amount of evaporation that has taken place, which in turn depends on the age of the water in each lake. With this in mind, the TDS levels in each of the lakes varies predictably. From

December, 1971 through June, 1972, the water supply to the lakes entered Lake No. 1, and any irrigation water used was taken out from Lake No. 3. During this period Lake No. 1 had the lowest TDS and Lake No. 3 had the highest. Then in the first week of June, 1972, the flow pattern through the lakes was changed so that the fresh water entered via Lake No. 3 and the irrigation water was taken out from Lake No. 1. This change is reflected in Figure 58. Prior to June, Lake No. 3 had the highest TDS levels. After June, Lake No. 3 had the lowest TDS levels. Throughout the year, the TDS values ranged from 800 mg/l to slightly over 1200 mg/l.

Alkalinity, pH and Carbon Dioxide

Alkalinity and pH are shown in Figures 59 and 69. After the water has been in the lakes the alkalinity rises from an average of 85 mg/l (as $CaCO_3$) in the plant effluent to 148 mg/l in the lake. Also, the pH goes from an average of 6.7 in the plant effluent to 8.4 in the lakes. The rise in these two quantities is probably due to exposure to the alkaline soils lining the lakes, the biological activity of the algae in the lakes, and to the effect of evaporation.

The variation in alkalinity between individual lakes is shown in Figure 59. The increase in alkalinity due to evaporation follows the same pattern as was the case with TDS. Also, Figure 70 shows the variation in alkalinity with depth. Alkalinity tended to be slightly higher near the bottom of the lakes than at the surface. The average pH values tended to be slightly lower at the bottoms of the

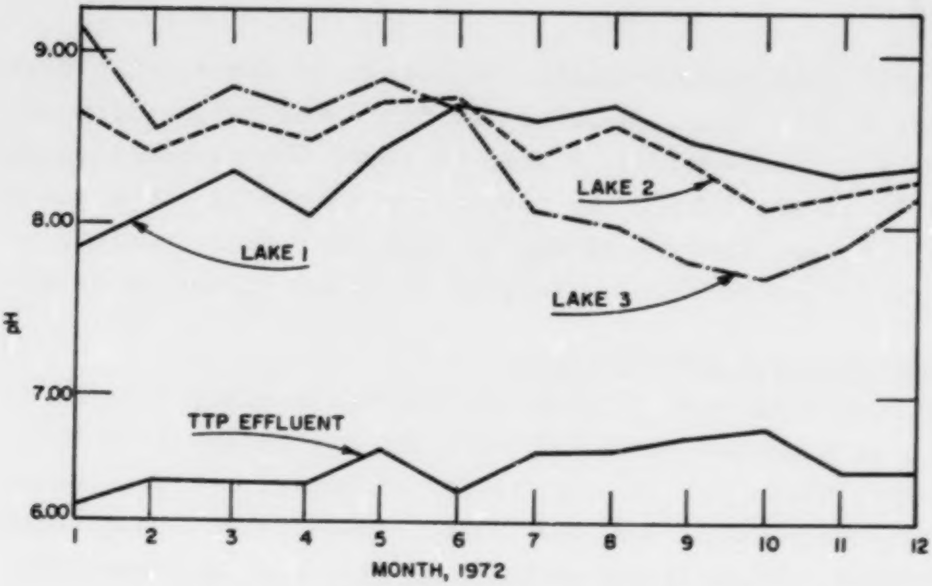


Figure 69 COMPARISON OF pH LEVELS, INDIVIDUAL LAKES AND TERTIARY PLANT EFFLUENT

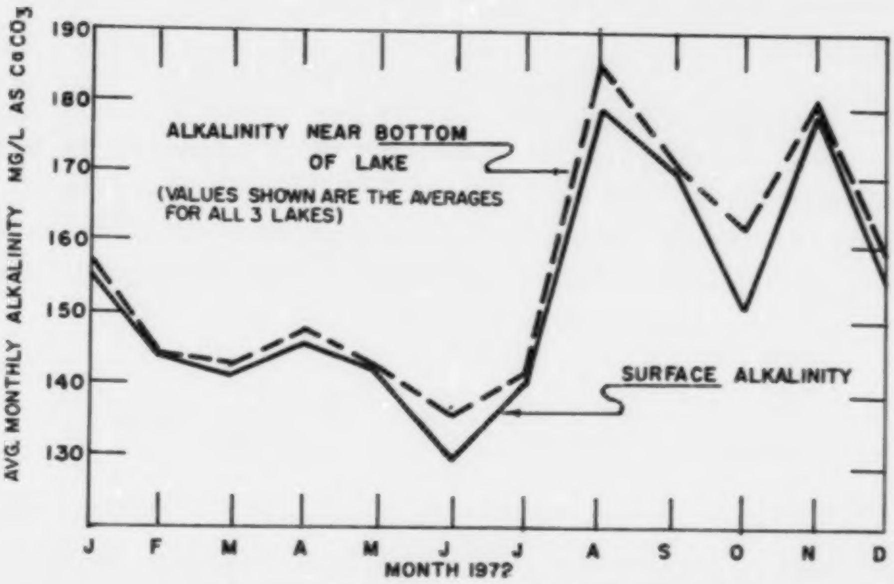


Figure 70 COMPARISON OF SURFACE AND BOTTOM ALKALINITY IN LAKES

lakes, but the difference was normally less than a tenth of a pH unit.

Normally the photosynthetic processes of the aquatic plants cause a rise in pH whenever the dissolved carbon dioxide supply is inadequate. Figure 71 shows the carbon dioxide levels in the lakes. By comparison to the pH curve shown also in that Figure, it may be seen that those periods of lower carbon dioxide correspond to rises in the pH level.

Other Chemical Constituents

Figures 72 through 77 show the average monthly values of some of the other chemical constituents measured in this study. These are the charts for hardness, sodium, potassium, boron, COD, BOD, and MBAS. These constituents were measured routinely for background data and to permit the early detection of any unsatisfactory developments in lake performance. None of these seemed to importantly affect the appearance, algal growth, or health aspects of the lake performance.

Suitability for Irrigation

Of the many water quality characteristics measured in this study, those that are most important in evaluating the suitability of the water for irrigation are total dissolved solids, sodium percentage, and boron. The average values of these characteristics are:

TDS	974 mg/l
Sodium Percentage	78-80%
Boron	1,38 mg/l

These are based on values obtained throughout 1972 in the Apollo Lakes, the source of irrigation water for Apollo Park. As shown in Figures 58 and 73 the values for TDS

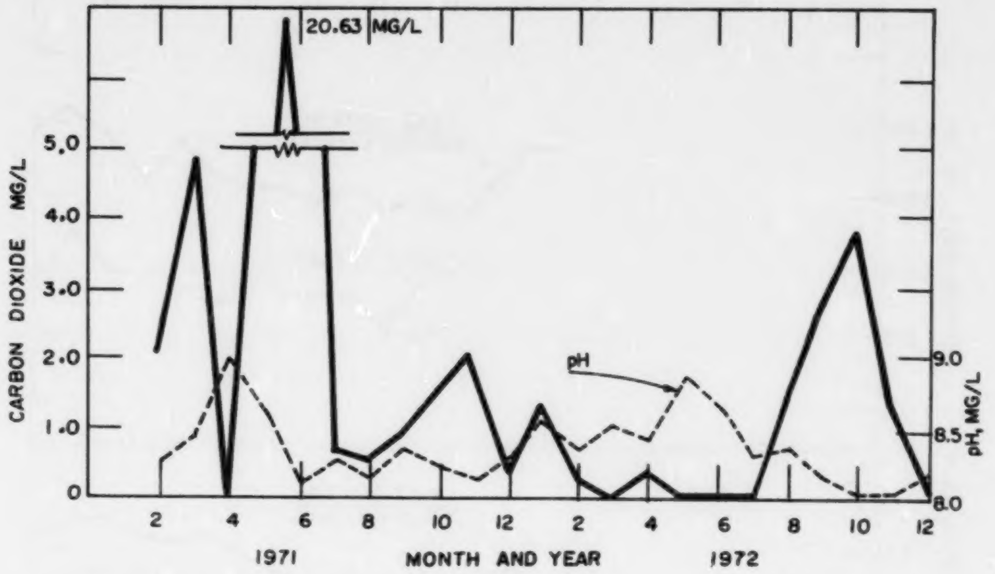


Figure 71 AVERAGE MONTHLY CARBON DIOXIDE IN LAKES

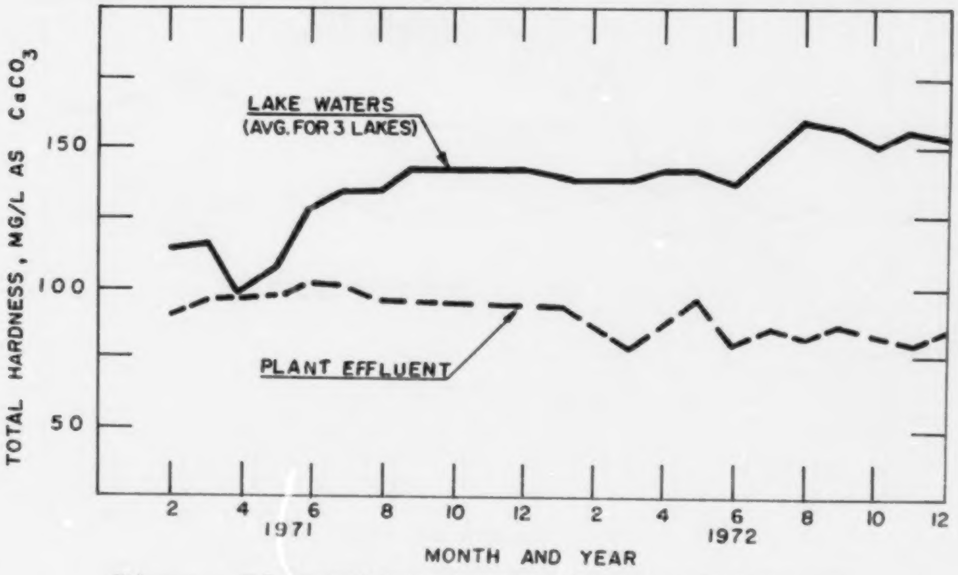


Figure 72 AVERAGE MONTHLY TOTAL HARDNESS IN LAKES AND TERTIARY TREATMENT PLANT EFFLUENT

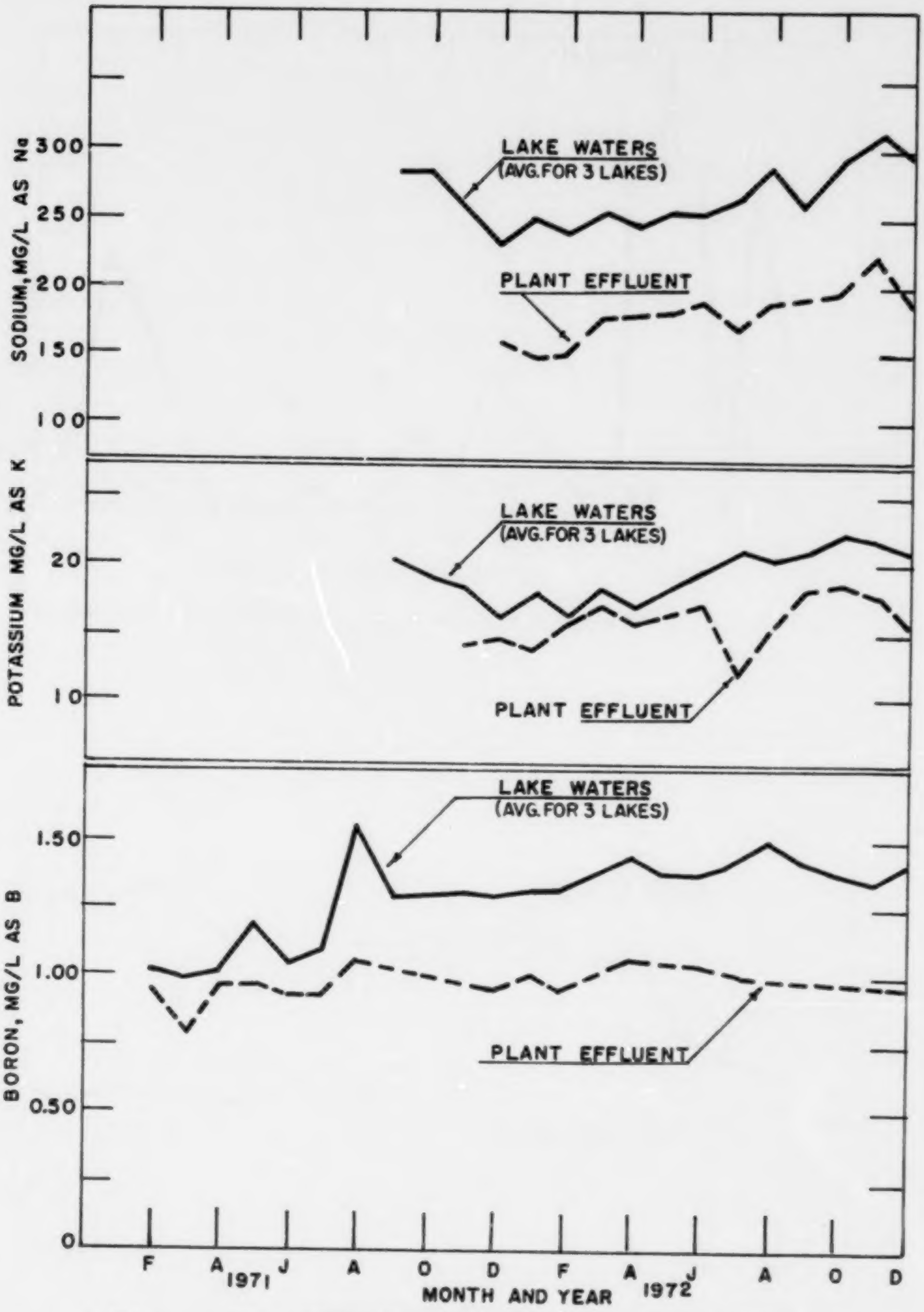


Figure 73 AVERAGE MONTHLY SODIUM, POTASSIUM, AND BORON CONCENTRATIONS--LAKES AND TERTIARY TREATMENT PLANT EFFLUENT

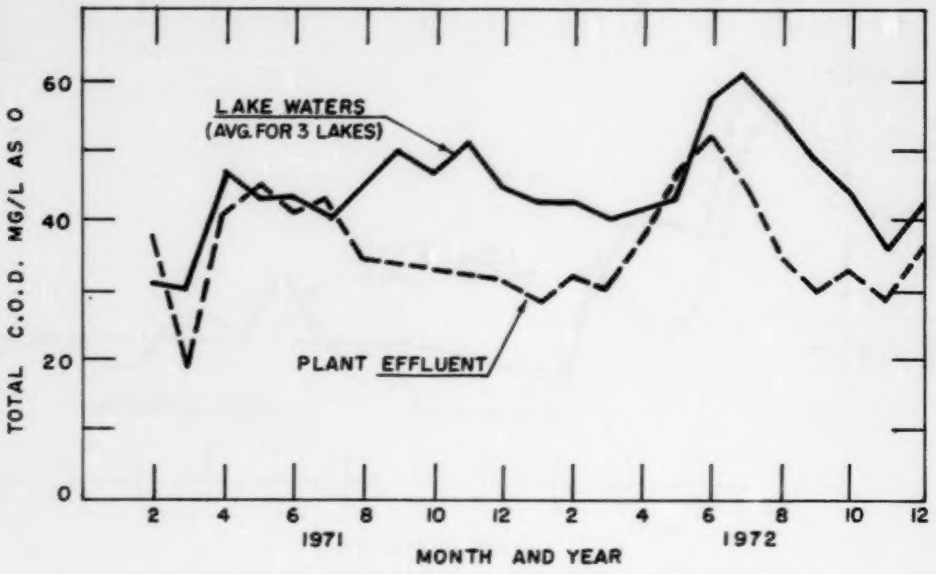


Figure 74 AVERAGE MONTHLY TOTAL COD
LAKES AND TERTIARY TREATMENT PLANT

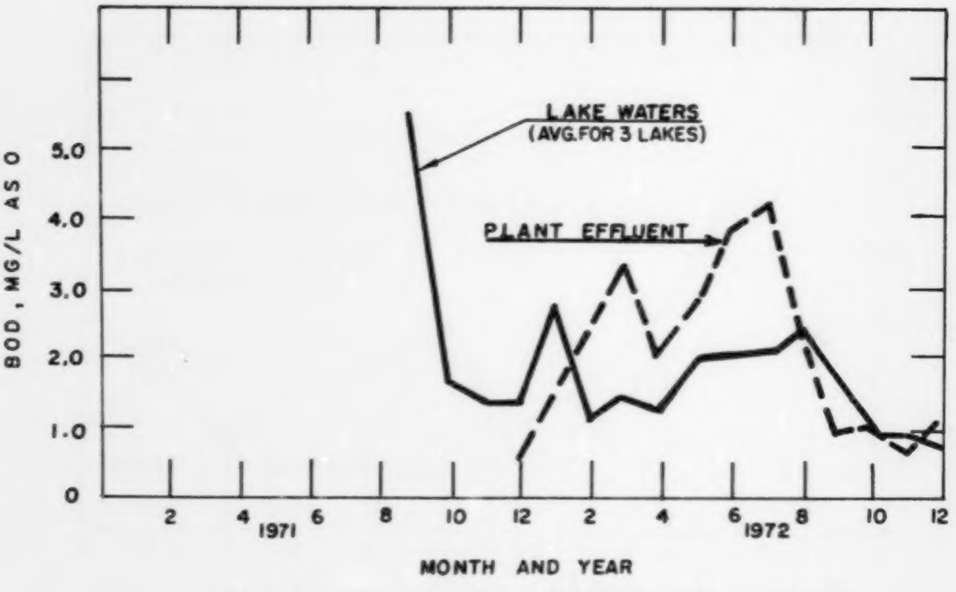


Figure 75 AVERAGE MONTHLY BOD - LAKES
AND TERTIARY TREATMENT PLANT

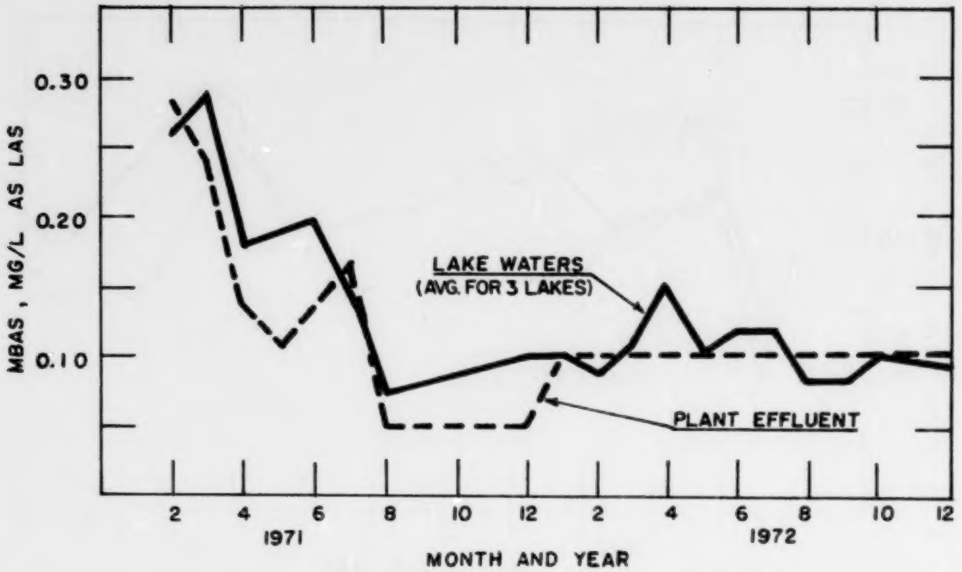


Figure 76 AVERAGE MONTHLY MBAS CONCENTRATION LAKES AND TERTIARY TREATMENT PLANT EFFLUENT

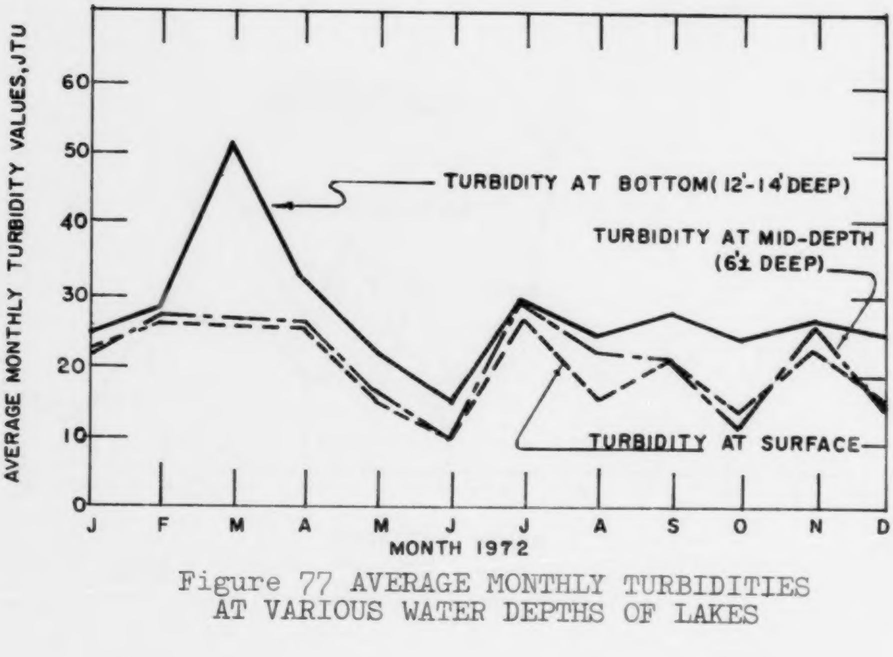


Figure 77 AVERAGE MONTHLY TURBIDITIES AT VARIOUS WATER DEPTHS OF LAKES

and boron in the lakes are higher than in the tertiary plant effluent. This difference is due to evaporation.

The total dissolved solids (TDS) in irrigation water largely consist of salts of calcium, magnesium, sodium and potassium. If the concentration of these salts is too high, the ability of the plants to absorb nutrients will be impaired, the chemistry of the plant metabolism may be affected, and soil permeability may be reduced. Generally, TDS levels over 700 mg/l will be harmful to some plants, and concentrations over 2000 mg/l are harmful, in some degree, to almost all plants.

The salinity hazard arising from high TDS levels is also often evaluated on the basis of specific conductance, which, for this water is in the 1300-1500 micromhos/cm range. By this criterion the water would be classified according to U.S. Department of Agriculture standards as bearing a "high" salinity hazard (Millar, et al[32]).

If the irrigation water has a high sodium percentage (that is, where the sodium ion concentration is high in comparison to other exchangeable cations such as calcium, magnesium, and potassium), the water will tend to cause alkali soil conditions, reducing permeability and increasing soil pH. It is normally desirable to have a sodium percentage of less than 60% and the lower the better. As this water has a sodium percentage consistently in the 78-80% range, its irrigation use could lead to alkali soil conditions unless precautions are taken.

The boron concentration in the lake water is important in this case because, as explained below, the park soils already have boron levels higher than desirable. The boron levels of the Apollo Lakes water ranges from 1.29 to

1.52 mg/l with an average of 1.38 mg/l. Water such as this with boron concentrations between 1.33 and 2.00 mg/l are normally classified as "permissible" waters for use with semitolerant crops (Millar, et al[32]).

The soil conditions in the park must be considered together with the irrigation water quality. Before the park was constructed it was learned that the soils in the area were characterized by saline-alkali conditions, aggravated by high boron concentrations. (Final Report, Waste Water Reclamation Project for Antelope Valley[3]). The average chemical characteristics for the native soil are shown in Table 33.

Table 33 CHEMICAL CHARACTERISTICS OF NATIVE SOILS, APOLLO PARK

Characteristic	Units	Top Soil (0-15 cm)	Sub Soil (15-80 cm)
Salinity (as conductivity)	millimhos/cm	5.7	25
Boron	mg/kg	20	80
Ca^{++}	meq/l	1.4	1.2
Mg^{++}	meq/l	0.5	1.2
$Na + K^+$	meq/l	55	249
Ca^{++} percentage	%	2	0.5
$CaCO_3$	None	Very low	Moderate to high

A soil reclamation project was made a part of the original construction contract for the park. The specific procedures recommended for the soil reclamation are described in Section V of this report. Basically these consisted of applying gypsum to the soil and leaching it with water. The goal of the reclamation project was to obtain the following soil characteristics (as measured on saturated soil paste extracts).

1. Salinity: not more than 2 millimhos/cm.
2. Alkali: exchangeable sodium percentage not more than 15%.
3. Boron: not more than 0.7 mg/l

Because of unforeseen problems explained in more detail in Section V, the reclamation program could not be completed as originally planned. Consequently, when the park was completed the average soil characteristics were:

1. Salinity: 4.75 millimhos/cm
2. Alkali: Exchangeable sodium percentage= 7.6%
3. Boron: 6.6 mg/l

The application of gypsum and leaching water appears to be a satisfactory reclamation method and should be continued. For, in spite of the difficulties in obtaining leaching, the reclamation efforts throughout the construction period did result in some improvement in the salinity and boron levels. Now that the park has a grass cover to impede runoff, more effective percolation, and therefore more effective reclamation, will be possible.

The application of leaching water alone (i.e., without gypsum) is not recommended. The removal of salts from an alkali soil may reduce the soil permeability and make further leaching impossible. (Hausenbuiller[33], Millar, et al[32]). Therefore the leaching must be done together with a process that will displace the exchangeable sodium. The use of gypsum as an amendment does this by supplying soluble calcium for exchange with sodium.

Because of the high TDS, sodium percentage and boron concentration in the lake water, its use as irrigation water will require continuing attention. A program of over-irrigating the park during the late fall, winter, and early spring months may be advisable if weather conditions permit. The normal irrigation and evaporation demands are much lower during this period and thus it would be possible to replace a part of the lake water with tertiary plant effluent of much lower TDS and boron concentration. Furthermore, the excess water percolating through the soils would, if accompanied by gypsum, improve the soil conditions. In short, the effect of such a program would be to flush both the lakes and the soils.

Overall, the irrigation quality of this water is low but usable, especially when considered together with the adverse soil conditions in this park. Even though relatively salt tolerant plants and grasses were planted in this park, it will be important to continue the soil reclamation, and to monitor the quality of the irrigation water.

INSECTS AND WILDLIFE

Insect development in these lakes followed a more or less classical pattern. All arthropod specimens collected belonged to the class insecta, and were typical of a fresh water environment. The principal species are listed in Figure 78.

Several collections were made of the water snail, Physa spp. This is a potential harborer of the cercaria which can cause swimmers' itch. However, this particular mollusk was not found in significant numbers.

Of the crustaceans that developed in these lakes, the principal species were daphnia, amphipods, "scuds", isopods, and cyclops. All of these were most commonly seen during the warmer weather. The water and shore birds found were mainly killdeers, plovers, and coots.

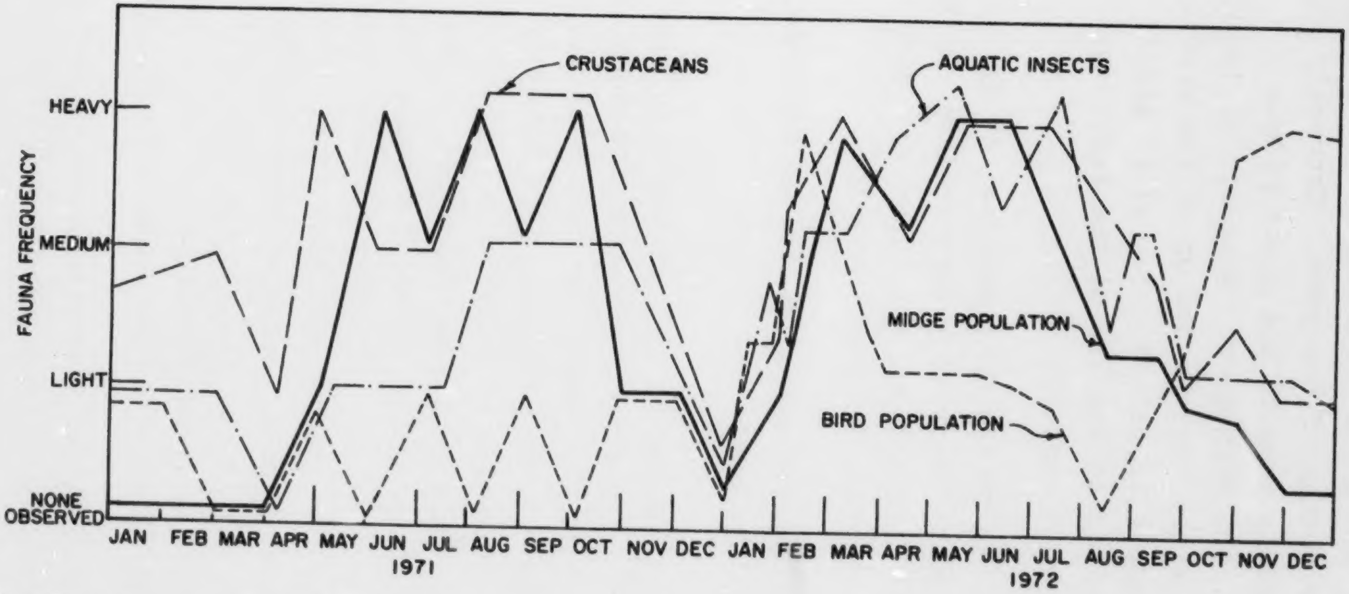
Figure 78 illustrates some of the observed variations in fauna levels. For 1971, the fauna frequency was more significant during the warmer months of the year. Extremely large populations of aquatic insects and adult midges occurred in May, August, and September. Windrows of larval and pupal exuvia (cast skins) were washed up on the shores. This growth was mostly noted in Lake No. 3. Adult midges sought refuge from the winds in the lee of the restrooms and were noted there in vast numbers.

Midges, which belong to the family Chironomidae, do not bite or sting people, but by their very numbers they can be an unpleasant nuisance. Fortunately, the lakes were not open to the public at the time of these outbreaks.

Arthropods and other fauna were easily collected throughout the year, even in the coldest periods.

The peaking of the aquatic fauna in 1972 occurred in late spring and early summer. The midge population was much less observable in 1972. A possible reason for this was that the soil washed into the lake in the winter of 1971 included dried sewage sludge, which had been added as a soil conditioner and fertilizer. This rich material aided in the growth and development of the midge larvae and pupae, and the massive population explosion. Probably, most of this fertilizer was dissipated or diluted the next year, leading to a much less noticeable problem. Because many species of immature midges use the nutritious silt on the lake bottom as a habitat or food supply, it is important to limit the amount of organic debris which could accumulate in the lakes.

No significant mosquito breeding developed at these lakes. This was primarily due to the absence of any substantial aquatic vegetation in the shoreline areas to provide



Most Commonly Found Fauna:

Midges: *Chironomous* Spp.

Aquatic Insects: Diving Beetles, *Hydrophyllidae* ; Shore Flies, *Ephydridae*
Back Swimmers, *Notonectidae* ; Water Boatmen, *Corizidae* ;
Damsel Flies, *Ephemeridae* ; Dragon Flies, *Odonata*

Crustaceans: Daphnia, Amphipods, Scuds, Isopods, *Cyclops*

Bird Life: Killdeers, Plovers, Coots

Figure 78 FAUNA FREQUENCY IN APOLLO COUNTY PARK

protection for breeding sites. The soil-cement lining, which extended to a depth of 61 cm. (2.ft.) below water surface, helped in this respect.

LAKE APPEARANCE

An aesthetic evaluation of the lakes was based on the factors of algae growths, water weeds, turbidity and color, insects, and odors. From such an aesthetic point of view the lakes performed very well.

Algae and Aquatic Plant Growths

As indicated earlier in this report, free-swimming algae blooms were never a serious problem in terms of lake appearance. Although isolated phytoplankton blooms occurred (over 20,000 cells/ml) most of the time, the algae levels were less than 10,000 cells/ml, and zero counts were very frequently obtained.

Floating mats of filamentous algae such as *Sirogonium*, *Spirogyra*, and *Anabaena*, water weeds such as Zannichellia, and interwoven mats of these growths were more of an aesthetic threat. However, because of the wind conditions these mats were driven to the shores of Lake No. 3, as shown in Figure 49, and this concentration considerably simplified the maintenance needed to control this problem. The most direct and effective solution to this problem was to mechanically remove these growths and dispose of them off-site. Also, repairs to the runoff protection berms should be very helpful in controlling future occurrences of this problem. This would limit fertilizers being carried in by sprinkler runoff.

Turbidity

Turbidity was a much more noticeable factor in these lakes than were algae or plant growths. Measured turbidity levels varied from 9 to 33 in Jackson Turbidity Units. This was mainly caused by the wave action stirring up sediment and by dust blown into the water by the predominate winds of the area. As evidence of this, an analysis of the suspended solids has shown that it is principally inorganic, i.e., non-volatile. The volatile suspended solids have accounted for 2.8% to 8.5% of the total suspended solids. Semiquantitative spectrographic analyses of this suspended matter has revealed that the most predominate element in the suspended matter is silicon, accounting for 17 to 25% of the suspended solids. Silicon is a common constituent of soils. Also, the soil lining the lake is very fine grained and the turbidity has appeared to vary as the amount of wind. A period of several consecutive fairly still days has often produced very clear lake water.

Turbidity varied with depth and generally higher values occurred near the bottom. Figure 77 shows the average monthly turbidity profiles for 1972.

CONCLUSIONS

The waste water reclamation and reuse concept has been successfully applied in the Apollo Park project. This has been done in spite of the difficulties caused by adverse soil conditions and high evaporative water losses.

All of the performance goals set for these lakes have been met, with the one exception of the mercury contamination of the fish. However, the evidence indicates that this problem was not due to any defect in the reclamation process, but was instead the result of an unforeseen natural soil condition in the area.

The water quality in these lakes has generally been very good. All health requirements have been met, and the water has had a satisfactory appearance. While the irrigation quality of the water is not high, it is usable for this purpose provided measures are taken to improve soil characteristics. If the problem of runoff carrying fertilizers into the lakes is controlled, eutrophication will not be a threat.

The lakes have proven to be a good environment for fish life and well suited to the reproduction of warm water fishes. The mercury contamination that did occur, while exceeding the U.S. Food and Drug Administration limit for human consumption, had no noticeable effect on the health of the fish. Rainbow trout can survive in these lakes the year round, and, if the mercury contamination can be stopped, a successful warm water fishery can be reestablished.

The mercury found in the fish enters the fish either directly from the water, or indirectly via the food chain. Apparently the mercury enters the water and food chain by the biological methylation of inorganic divalent mercury from the sediments. Mercury may possibly be entering the lakes from wind blown soils which are high in mercury concentration and which are settling into the lakes.

SECTION IX
ACCEPTANCE AND USE OF LAKES AND PARK

INTRODUCTION

One of the main objectives of the Antelope Valley Waste Water Reclamation Project was to demonstrate the acceptability by the public of the use of reclaimed waste water for establishing attractive aquatic recreational facilities, especially in water-short desert areas.

The program consisted of two primary plans. The first was an extensive public relations effort consisting of oral and written presentations, newspaper and magazine items, and radio and television announcements. The second was to create the most aesthetically pleasing aquatic park as possible so that the public would have the desire to use the facilities.

From the tremendous public support we received during the pilot plant studies, we anticipated even greater enthusiasm and participation in the construction of the full-scale project. This goal was obtained--the many people now using the park do not even think of the source of the water, although there are warning signs posted.

The recreational features are open and accessible the year round to the general public on a non-discriminatory basis, and completely operated and maintained under the jurisdiction of the County of Los Angeles.

PUBLIC ACCEPTANCE

The reaction to this project by the public has been one of overwhelming acceptance as attested to by the numerous requests for presentations and written information from science-oriented corporations, scientific groups, public agencies, colleges, universities, service clubs, and the ecology-concerned taxpayer.

Local Group Support

To acquire local acceptance of this project, many presentations were made by the Department of County Engineer. Such presentations were made to the following organizations, sometimes several times over the years, and, in every case, the organization not only accepted this new concept, but also gave of their time and support.

Lancaster Optimist Club
California Regional Water Pollution Control Board, Lahontan Region
Mariposa School PTA--Lancaster
California Water Pollution Control Association
Antelope Valley Progress Association
Lancaster Chamber of Commerce
Del Sur Grange--Lancaster
Antelope Valley Industrial Fair
Antelope Valley Republican Womens' Club
Pomona Grange--Lancaster
Quartz Hill Womens' Club
Antelope Valley YMCA
President's Water Pollution Control Advisory Board--Los Angeles
County Water Resources and Reclamation Advisory Commission
Pearblossom Chamber of Commerce
Mariners Class, Presbyterian Church--Lancaster
Presbyterian Church of Lancaster
Sixth Grade Classes at Sierra School--Lancaster
Los Angeles Regional Planning Commission
California Water Pollution Control Association--Los Angeles Basin and Desert Sections

Los Angeles County Fish and Game Commission
Antelope Valley Kiwanis Club
Lancaster Women's Club
Hollywood Sunset Optimist Club

News Media

Support by the news media in over 120 newspaper and magazine articles for this project has been most rewarding. Table 34 tabulates these news sources and presentations.

Radio and Television

As a public service the following radio and television stations have broadcast information encouraging the project and its broader aspect of ecology:

KAVL Lancaster--Public Service
KRKD Los Angeles--Property Owners' Tax Association
KABC-TV--Public Service
KBIG Los Angeles--Public Service
KABC-TV Los Angeles--Ralph Story

Information Requests

Many requests for general and technical information have been received from organizations, agencies, and individuals from all over the United States, as tabulated in Table 35.

Five brochures, nine reports, and fourteen applications were prepared and distributed since the initiation of this project.

PARK OPENING

Apollo County Park was feted with two openings. One was on February 26, 1970, to celebrate the "Valve Opening", the delivery of the first reclaimed waste water to the park lakes, and one on November 4, 1972, to dedicate and open the park in honor of the Apollo 11 Astronauts.

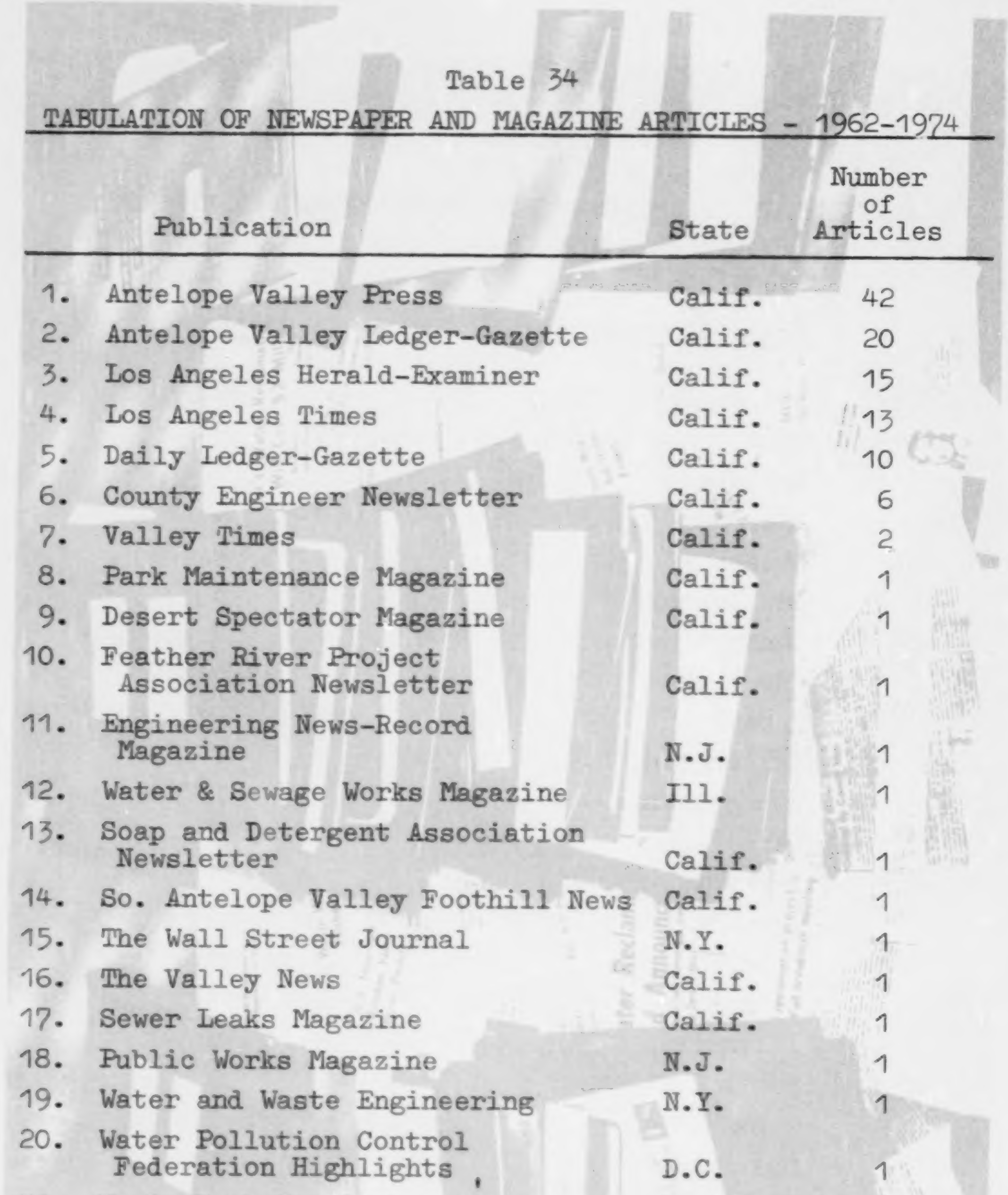


Table 34

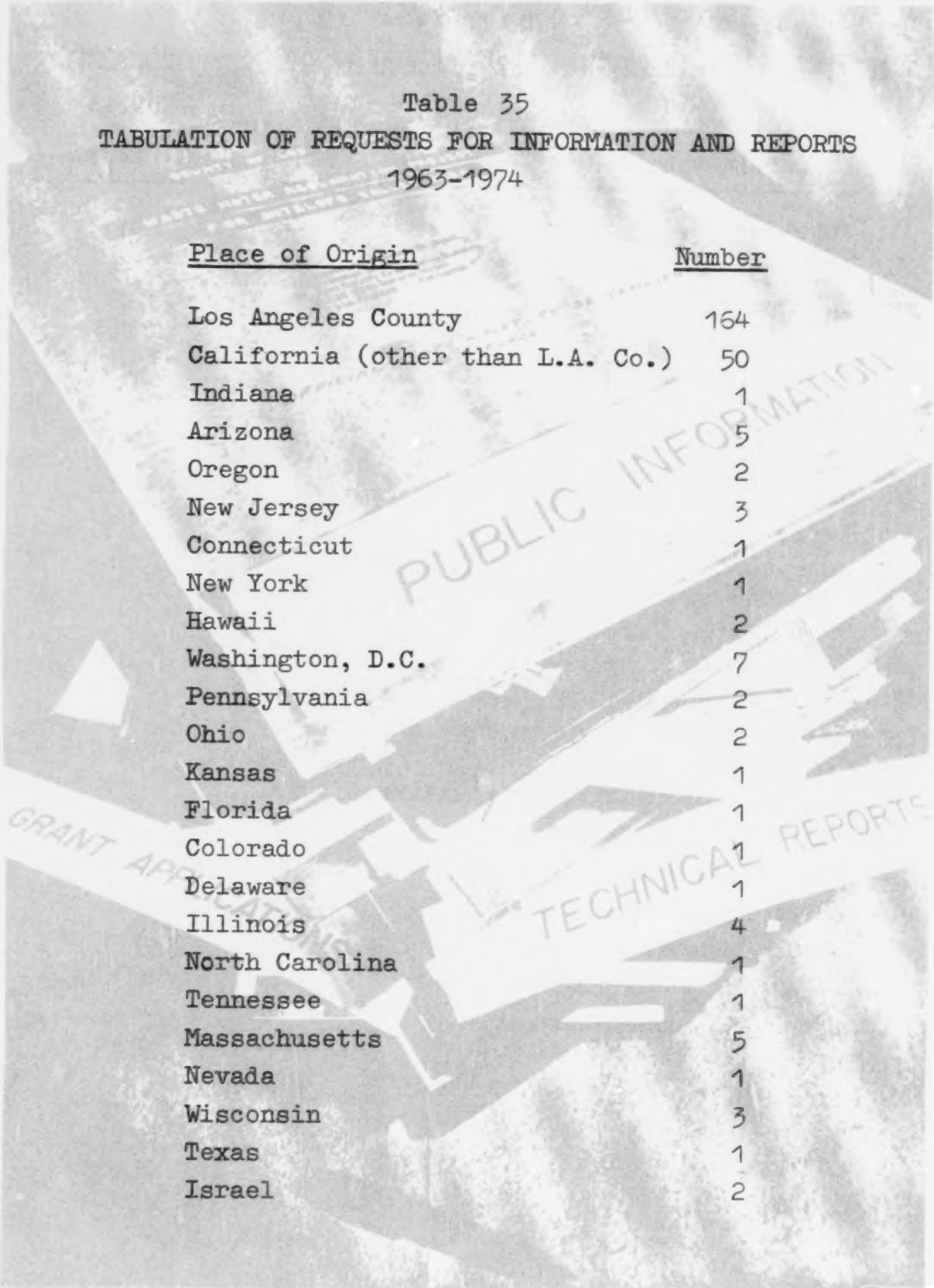
TABULATION OF NEWSPAPER AND MAGAZINE ARTICLES - 1962-1974

	Publication	State	Number of Articles
1.	Antelope Valley Press	Calif.	42
2.	Antelope Valley Ledger-Gazette	Calif.	20
3.	Los Angeles Herald-Examiner	Calif.	15
4.	Los Angeles Times	Calif.	13
5.	Daily Ledger-Gazette	Calif.	10
6.	County Engineer Newsletter	Calif.	6
7.	Valley Times	Calif.	2
8.	Park Maintenance Magazine	Calif.	1
9.	Desert Spectator Magazine	Calif.	1
10.	Feather River Project Association Newsletter	Calif.	1
11.	Engineering News-Record Magazine	N.J.	1
12.	Water & Sewage Works Magazine	Ill.	1
13.	Soap and Detergent Association Newsletter	Calif.	1
14.	So. Antelope Valley Foothill News	Calif.	1
15.	The Wall Street Journal	N.Y.	1
16.	The Valley News	Calif.	1
17.	Sewer Leaks Magazine	Calif.	1
18.	Public Works Magazine	N.J.	1
19.	Water and Waste Engineering	N.Y.	1
20.	Water Pollution Control Federation Highlights	D.C.	1
21.	Eagle Rock Sentinel	Calif.	1
22.	Water in the News Newsletter	Calif.	1

Table 35

TABULATION OF REQUESTS FOR INFORMATION AND REPORTS

1963-1974



Place of Origin	Number
Los Angeles County	164
California (other than L.A. Co.)	50
Indiana	1
Arizona	5
Oregon	2
New Jersey	3
Connecticut	1
New York	1
Hawaii	2
Washington, D.C.	7
Pennsylvania	2
Ohio	2
Kansas	1
Florida	1
Colorado	1
Delaware	1
Illinois	4
North Carolina	1
Tennessee	1
Massachusetts	5
Nevada	1
Wisconsin	3
Texas	1
Israel	2

The valve opening ceremony was hosted by the Los Angeles County Board of Supervisors, the County Engineer Department and the Sanitation Districts, and was attended by publishers and editors of the local newspapers, officals of the Chambers of Commerce, California Regional Water Quality Control Board, California Department of Water Resources, United States Forestry Service, Los Angeles County departmental directors or representatives and many local residents and school children. Highlighting the day's festivities was the first rush of water into Lake No. 1, for the eventual filling of the lakes.

The dedication of the park late in 1972 in honor of the Apollo 11 Astronauts, hosted and attended by many of the same dignitaries, was made special by the attendance and presentation by Astronaut Edwin "Buzz" Aldrin. Colonel (USAF, Retired) Aldrin called the park and the use of reclaimed water an indication of man's new outlook on his environment. He continued to describe his thoughts and experiences on the moon expedition, noting the important functions of the capsule as restored by the simulated capsule housed in the special park building.

FUTURE PROSPECTS

Considering that the boating concession was not up to the required number of boats and that fishing was just recently permitted, the park attendance has been more than satisfactory. As people of Southern California become more aware of this unique park and the recreational opportunities available, the per capita attendance should increase as well on a year-round basis. The adjacent County Airport also makes this park available for use by flyers from great distances.

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SECTION XI
GLOSSARY OF ABBREVIATIONS AND SYMBOLS

ABS	Alkyl-Benzene-Sulfonate
AC	Asbestos Cement
ac ft	acre-feet
alum	Aluminum Sulfate
A.S.T.M.	American Society for Testing Materials
A.W.W.A.	American Water Works Association
BHP	Brake Horsepower
Bldg	Building
BOD	Biological Oxygen Demand
cm	centimeter
cm/sec	centimeter per second
COD	Chemical Oxygen Demand
dia	diameter
DO	Dissolved Oxygen
el.	elevation
Eff. (%)	Efficiency in Percent
ESP	Exchangeable Sodium Percentage
fin	finish
fpm	feet per minute
fps	feet per second
ft	feet
ft^2	square feet
ft^3	cubic feet
gal	gallon
gpd	gallons per day
gpd/ft^2	gallons per day per square foot
$gal/ft^2/min$	gallon per square foot per minute
gph	gallons per hour
gpm	gallons per minute
HP	Horsepower

ha	Hectare
in	inches
in^2	square inches
in/yr	inches per year
JTU	Jackson Turbidity Units
Kg	Kilogram
Kg/cm^2	Kilograms per square centimeter
Kg/day	Kilograms per day
Kg/ha/day	Kilograms per hectare per day
l	liter
l/sec	liter per second
l/m^2/min	liters per square meter per minute
lb	pound
lb/day	pounds per day
lb/ac/day	pounds per acre per day
m	meter
m^2	square meters
m^3	cubic meters
m/day	meters per day
m^3/sec	cubic meters per second
max	maximum
MBAS	Methelene Blue Activated Substances
mgd	million gallons per day
mg/l	milligrams per liter
mho	conductance unit
min	minimum
ml	milliliter
mm	millimeter
MPN	Most Probable Number
MPN/100 ml	Most Probable Number per One Hundred millimeters
oc	on center
OSI	Organic Sediment Index

ph	phase
pH	acidity level
ppm	parts per million
psi	pounds per square inch
rpm	revolutions per minute
t	metric ton
tons/ac-ft	tons per acre-foot
TDS	Total Dissolved Solids
TTP	Tertiary Treatment Plant
typ	typical
v	volts
VCP	Vitrified Clay Pipe
WI	Wrought Iron
WRP	Water Renovation Plant
ws	water surface
°C	degree Centigrade
°F	degree Fahrenheit
'	foot
"	inch
@	at
<	less than
>	more than

APPENDIX A
OPERATION MANUAL
for the
ANTELOPE VALLEY TERTIARY TREATMENT PLANT

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SECTION I
INTRODUCTION AND DESIGN DATA

PURPOSE OF PROJECT

The Antelope Valley Tertiary Treatment Plant was constructed for the specific purpose of providing nutrient free, disinfected water for recreational use at Apollo County Park, an aquatic recreational facility approximately 1.86 Km (3 mi.) from the treatment plant site. This plant, operated by the Sanitation Districts of Los Angeles County, is part of the Antelope Valley Water Reclamation Project. The feasibility of reclamation and reuse of available waste waters is also a factor to be determined since the project is in an area where the water supply must be conserved. This program is managed by the Los Angeles County Engineer with federal financial assistance through the Environmental Protection Agency. Waste discharge requirements for the tertiary treatment plant were set forth by the California Regional Water Quality Control Board, Lahontan Region, in Resolution 66-9. These discharge requirements are as follows:

Waste Discharge Specifications

1. There shall be no overflow or discharge of treated or untreated effluent from the treatment or recreational system to adjacent land areas or surface waters, except a discharge may be permitted to the Amargosa Creek at designated locations.

2. The operation of the recreational lakes and irrigation facilities and the discharge of waste waters to the Amargosa Creek shall not create a nuisance.

3. There shall be no adverse effect on the beneficial uses of the surface or ground waters of the area as a result of the discharge of waste waters into the

recreational lakes onto the irrigated park area, or into Amargosa Creek.

4. Unauthorized persons shall be effectively excluded from the treatment area.

5. Adequate protective measures shall be taken by the discharger to prevent these disposals of waste water from adversely affecting fish and wildlife.

6. These discharges shall not result in any objectionable taste, odor, color, or foaming in the receiving waters.

7. These discharges shall not raise the concentration of minerals in the receiving waters to toxic levels.

8. The discharger shall conform with all regulations of the State and local health departments.

9. A monitoring program, approved by the staff of this board shall be established by the discharger prior to any discharge.

Additional effluent quality requirements were set forth and are as follows:

1. Effluent total phosphate concentrations shall not exceed 0.5 mg/l as PO_4.

2. Turbidity shall not exceed five (5) Jackson Turbidity Units (JTU).

3. Ammonia-nitrogen concentrations shall not exceed 1 mg/l.

4. The median most probable number (MPN) of coliform organisms shall not exceed 2.2 per 100 ml.

5. Water shall not contain substances in toxic concentration.

6. Final effluent shall be demonstrated to be virus free.

PROJECT DESCRIPTION

Location

The Antelope Valley Tertiary Treatment Plant is located at the County Sanitation District No. 14 Water Renovation Plant approximately 5 miles north of Lancaster proper. The District 14 Plant serves the Lancaster area and supplies influent to the tertiary facility.

A set of contract drawings (14-g-35) and specifications (File: 14-951.5) for the tertiary plant can be obtained from the Files Section at the County Sanitation Districts of Los Angeles County, Joint Administration Office (JAO). A copy of the contract drawings is on file at the tertiary plant.

Influent Water Characterization

The District 14 Plant consists of primary sedimentation followed by biological stabilization in oxidation ponds. This oxidation pond water is well oxidized, contains low-ammonia concentrations and a reduced BOD. The water does however, contain high algae counts, and bacterial populations which must be removed in the tertiary treatment process. The essential nutrient, phosphorus, also abounds in the pond water. The total phosphate concentration is higher in the winter and spring than in the summer and fall. The influent flowrate varies from low flows during the winter months to high flows during the summer months.

Tertiary Treatment Plant

The Tertiary Treatment Plant was designed using modified water treatment practices. The process utilized features treatment with alum, flocculation, sedimentation, filtration and chlorination. The layout of the plant is shown in Figure 10 and the flow scheme and hydraulic profile are presented in Figure 11.

In general the influent water is treated in the sequence below:

1. Source Water from Oxidation Ponds
2. Influent Pump Station
3. Chemical Feed
    a. Liquid aluminum sulfate ($Al_2(SO_4)_3$)
    b. Pre-chlorination
4. Flocculation Chamber
    a. Paddle flocculators agitate chemical and influent mixture to form floc particles.
5. Sedimentation Tank
    a. Sludge sent to plant waste sump.
    b. Effluent to dual media filter.
6. Dual Media Gravity Filter
    a. Backwash wastewater to plant waste sump.
    b. Filtrate chlorinated and sent to contact chamber.
7. Chlorine Contact Chamber
    a. Supplies washwater to filter.
    b. Quality Effluent to effluent pump station.
    c. Unacceptable effluent to District 14 Plant influent wetwell.
8. Effluent Pump Station
    a. Effluent to recreational lakes (Apollo County Park)

9. Auxiliary Systems
    a. Plant Waste Sump
    b. Pipe Gallery Sump Pump
    c. Instrument Air Compressor
    d. Instrumentation

Governing parameters of tertiary treatment plant operations are monitored and recorded daily on the Monthly Summary of Operation sheet. Completed sheets are sent to the Plant Evaluation Engineer for processing.

DESIGN CRITERIA

The design criteria for Stage I operation is summarized on the following table:

Table 36

ANTELOPE VALLEY TERTIARY TREATMENT PLANT

DESIGN DATA

Note: All loading rates are based on average flow conditions, except as noted.

Plant Effluent Flow	
Stage I	21.905 l/sec (0.5 mgd)
Stage II, (Future Expansion)	43.81 l/sec (1.0 mgd)
Influent Loading	
Suspended Solids (S.S.)	100 mg/l
BOD 5 days @20°C	32 mg/l
COD	184 mg/l
Influent Pump	
Capacity	47.756 l/sec (1.09 mgd)
Drive	Variable Speed

Table 36, Continued

DESIGN DATA

Chemical Feed System	
Prechlorination	
Type	Solution Feed
Capacity	30 mg/l
Average Chlorine Dose	10 mg/l
Alum Feed	
Type	Liquid $Al_2 (SO_4)_3$
Pump Capacity	1.32 l/min (20.8 gph)
Max. Dose	526 mg/l
Design Dose	300 mg/l
Storage Tank Capacity	21.2 m^3 (5600 gal)
Flocculation Chamber	
Flowrate	24.1 l/sec (0.55 mgd)
Tank Dimesnions	4.88x2.44x2.44m(16'x8'x8') SWD
Volume	29.0 m^3 (7,660 gal)
Detention Time	20 min.
Paddle Flocculators	
Number	2
Drive	Variable Speed
Speed Range	15.2-45.7 cm/sec (0.5-1.5 ft/Sec)
Sedimentation Tank	
Flowrate	24.1 l/sec (0.55 mgd)
Tank Dimensions	4.877x20.726x2.438m(16'x68'x8') SWD
Surface Area	101.1 m^2 (1088 ft^2)
Hopper Volume	25.5 m^3 (6747 gal)
Volume of Tank (incl. hopper)	272 m^3 (71,853 gal)
Overflow Rate	20.37 m^3/m^2 day (500 gpd/ft^2)
Detention Time	2-3 hours
Maximum Sludge Flow (Design)	5% Plant Flow

Table 36, Continued

DESIGN DATA

Sedimentation Tank - Con't.	
Maximum Sludge Flow (Attained)	15% Plant Flow
Maximum Sludge Concentration (Design)	3%
Maximum Sludge Concentr. (Attained)	0.3%
Flight Speed	58.4 cm/min (23 in/min)
Sludge Pump	
Capacity	2.1 l/sec (33 gpm)
Drive	Variable Speed
Filtration	
Flowrate	22.8 l/sec (0.52 mgd)
Filter Bed Area	16.7 m^2 (180 ft^2)
Loading Rate	1.3 l/sec/m^2 (2.0 gpm/ft^2)
Final Head Loss	2.1 m (7.0 ft)
Maximum Backwash Cycle	24 hours
Backwash Rate	12.2 l/sec/m^2 (18 gpm/ft^2)
Backwash Pump Capacity	205.0 l/sec (4.68 mgd)
Surface Wash	1.36 l/sec/m^2 @ 3.5 kg/cm^2 (2.0 gpm/ft^2 @ 50 psi)
Surface Wash Pump Capacity	22.7 l/sec (360 gpm)
Maximum Bed Expansion	50%
Filter Media	
#1-1/2 Anthracite	45.7 cm (18 in)
#20 Sand	22.8 cm (9 in)
Graded Gravel Support	45.7 cm (18 in)
Chlorine Contact Pond	
Flowrate	21.9 l/sec (0.50 mgd)
SWD	2.1 m (7 ft)
Volume	623 m^3 (164,560 gal)
Detention Time	8-10 Hours

Table 36, Continued
DESIGN DATA

Chlorine Contact Pond - Con't.	
Maximum Chlorine Dose	15 mg/l
Average Chlorine Dose	8 mg/l
Chlorinators	
Number	2
Type	Solution Feed
Capacity Each	30 mg/l
Effluent Pumps	
Pump #1 Capacity	23.7 l/sec (0.54 mgd)
Pump #2 Capacity	47.3 l/sec (1.08 mgd)

SECTION II

TERTIARY PLANT INFLUENT

CHARACTERISTICS

Influent to the tertiary treatment plant is provided by the oxidation ponds of the District 14 Water Renovation Plant. Under the present operating mode tertiary influent is drawn from Pond #1. This water has received approximately 60 to 120 days of secondary treatment and has the characteristics as shown in the following table:

Table 37

INFLUENT CHARACTERISTICS

Temperature (°F)	40-75
pH	8-10
Turbidity (JTU)	25-85
Alkalinity (mg/l as $CaCO_3$)	225-275
Hardness (mg/l as $CaCO_3$)	60-80
Suspended Solids (mg/l)	70-100
Total Dissolved Solids (mg/l)	600-650
COD (mg/l)	180-200
BOD (mg/l)	30-40
DO (mg/l)	3-30
Ammonia -N (mg/l)	0-2
Organic -N (mg/l)	8-20
Nitrate -N (mg/l)	0-1
Nitrite -N (mg/l)	0-2
Total Phosphates as PO_4 (mg/l)	20-40
Algae (counts/ml)	100,000-400,000

SECTION III
INFLUENT PUMP STATION

GENERAL

The influent pump station is one of the most important units in the tertiary treatment process. If it fails, the rest of the process can do nothing to treat the oxidation pond water. The basic function of the influent pump is to keep the plant supplied with the proper amount of flow to maintain the required treatment.

OPERATION

The influent pump unit consists of a Chicago Pump Company Model LM-4, 47.01 l/sec (760 gpm) capacity pump and a U.S. Motors Varidrive with output speeds ranging from 1170 rpm to 585 rpm.

Equipment Startup

To start the influent pump into automatic operation, the following steps should be performed:

1. All circuit breakers must be CLOSED.
2. All process valves must be in proper position. (See Section XIII, Instrumentation).
3. Activate chlorine and alum injection systems.
4. Place influent pump H-O-A switch in AUTO position.
5. Turn SHUT DOWN MANUAL SWITCH to the ON position. Reset the Switching Relay by manually tripping relay to activate the influent pump. (This Switching Relay is an electric interlock between the influent pump and the filter backwash system which prevents both from operating at the same time).

Special Conditions

The following Special Conditions govern the automatic operation of the influent pump:

1. Each time the INFLUENT PUMP STARTS, a timer LOCKS-OUT the high turbidity backwash initiating control signal for an adjustable time period. (0-30 min.)
2. The Backwash Pump and Influent Pumps run ALTERNATELY, except after plant shutdown when an electrical interlock relay returns to the "Backwash" position. Automatic startup of the Influent Pump cannot occur until this interlocking relay is manually reset to the Influent Pump position. (This interlock can also be reset to the Influent Pump position by manually turning the main Backwash Pump H-O-A switch to the HAND position momentarily).
3. The Influent Pump WILL NOT RUN automatically unless the following conditions are satisfied:
   a. Filter Wastewater and Backwash Throttling Valves must be CLOSED.
   b. Filter Effluent Valves must be OPEN.
4. The Sludge and Alum Pumps will NOT RUN automatically and the Chlorinator Solenoid Valve will NOT OPERATE unless the Influent Pump is RUNNING.

INDICATING LIGHTS, ALARMS

Indicating Lights

1. Switchboard #4

Status	Color
Circuit Breaker Closed	Amber
Starter Closed	Green

2. Metering and Control Panel

Status	Color
Control Power ON	Yellow
Filter Wastewater Valve CLOSED	Green
Backwash Throttling Valve CLOSED	Green
Filter Effluent Valve OPEN	Amber

OPERATING PROBLEMS AND SOLUTIONS

Foreign Material Caught in Flowmeter

1. Indicator:
   Meter stops functioning

2. Monitoring, Analysis, and/or Inspection:
   Open wye connection upstream of flowmeter for visual examination of pipe.

3. Corrective Measures:
   a. Remove foreign material by hand.
   b. Check positioning of screen covering inlet structure.

SECTION IV
CHEMICAL FEED SYSTEM

GENERAL

Chlorine and liquid aluminum sulfate ($Al_2(SO_4)_3$) are fed to the influent prior to entering the flocculation chamber. Prechlorination of the influent is performed at times to combat the effects of bacteria on the tertiary process. The liquid alum is used to coagulate the suspended solids, algae growths, and phosphates in the influent, and to improve the performance of the dual media filter.

OPERATION

Prechlorination

Chlorine is stored in one-ton cylinders in the south end of the control building. This gas is mixed with water in one of the two chlorinators adjacent to the storage cylinders and transported through a 3/4" PVC line to the pipe gallery where it is injected into the flocculation chamber influent line. The dose of chlorine used in this process varies from 6 to 11 mg/l. Additional information on the chlorine feed system is presented in Section VIII: Chlorination System.

Alum Addition

The alum feed system consists of a storage tank, an unloading compressor, an alum diaphragm pump, and piping. The liquid alum is stored in a 21.1 m^3 (5600 gallon), 3.048 m (10 ft) diameter, Poly-Bilt fiberglass tank located next to the dual media filter. A Wallace and Tiernan mechanical diaphragm, positive displacement pump is located at the base of the storage tank and is used to pump the liquid alum to the pipe gallery. Alum is injected into the influent line next to the prechlorination point. The quantity of alum injected is determined by reading the manometer on the side of the storage tank.

Alum dosage is adjusted manually by changing the stroke length of the pump. This is done by adjusting the control knob until the desired scale reading (1-10) is attained. The alum dose can be varied from 240 mg/l to 450 mg/l, dependent upon influent water conditions and seasonal changes. (Additional adjustment may be made by changing the multiple sheave pulleys.)

The rated capacity of the pump is 1.32 l/min (20.8 gph), which corresponds to a dosage of 526 mg/l with an influent flow of 24.1 l/sec (0.55 mgd) when the alum liquor is equivalent to 48.5% dry alum weight.

The alum diaphragm pump is electrically interlocked with the influent pump and filter backwash system. It only operates when the influent pump is running.

Alum Pump Startup (Automatic)

1. Backwash throttling valve must be CLOSED
2. Backwash sequence must be OFF
3. Influent pump must be RUNNING.
4. Valve between storage tank and alum pump must be OPEN.
5. Turn Pump H-O-A switch to AUTO.

Safety Precautions for Alum Handling

Alum is irritating to the skin and mucous membranes because of its acidic nature. Use extreme caution when working with the liquid alum and wear the proper protective clothing and eye protection.

1. Wear adequate protective clothing when handling alum liquor. Recommended protection consists of:
    - a. Safety hard hat.
    - b. Clear goggles or face shield.
    - c. Plastic or rubber gloves.
    - d. Rubber apron or slicker suit.
    - e. Rubber boots.
2. Avoid spillage, as spilled liquid alum becomes extremely slick upon slight evaporation, making stairways, walkways, and floors very dangerous.
3. Prevent the liquid alum from coming in contact with ferrous metals as the corrosive action is similar to that of sulfuric acid solutions.
4. First Aid. Whenever first aid is required, it should be given immediately. Prompt treatment may greatly decrease the severity of the effect. Medical attention should be obtained as soon as possible after injury, even if the injury appears slight. The physician should be given a detailed account of the incident.
    - a. Ingestion. Obtain medical attention as soon as possible. If aluminum sulfate has been swallowed, give large quantities of water to dilute the acid. Induce vomiting by giving warm salty water (2 tablespoons of table salt to a pint of water). If this measure is unsuccessful, vomiting may be induced by tickling the back of the patient's throat with the finger. Vomiting should be encouraged about three times or until the vomitus is clear. Additional water may be given to wash out the stomach.

b. Eye Contact. Immediately flush the eyes with large quantities of running water for a minimum of 15 minutes. Hold the eyelids apart during the irrigation to ensure flushing of the entire surface of the eye and lids with water. Obtain medical attention as soon as possible. Oils or ointments should not be used unless directed by a physician. Continue the irrigation for an additional 15 minutes if the physician is not available.

c. Skin Contact. Immediately flush affected areas with water and remove contaminated clothing.

d. Inhalation. Remove from contaminated atmosphere. If breathing has ceased, start mouth-to mouth artificial respiration. Oxygen, if available, should only be administered by an experienced person when authorized by a physician. Keep patient warm and comfortable. Call a physician immediately.

LIQUID ALUM UNLOADING PROCEDURE

The following procedure should be followed when unloading a shipment of alum liquor from a tank truck:

1. Have a truck back up to alum storage tank slab.
2. Loosen manhole on top of alum tank to ensure adequate venting and prevent failure of tank due to a surge of compressed air from empty tank truck.

NOTE: 2" PVC vent line alone is inadequate to handle a pressure surge.

3. Remove cover from 5.08 cm (2 in) PVC intake pipe at bottom of slab and connect feed line from tank truck.
4. Open valve on intake pipe.

5. Connect air hose from tank truck to alum truck unloading compressor.
6. Start compressor by pressing ON switch local to the unit. (Starter should be ON and Circuit Breaker should be CLOSED.)
7. Unloading a truck with a full load of approximately 16,655 liters (4,400 gal) will take approximately one hour.
8. When unloading is complete, reverse steps 1 through 6.

INDICATING LIGHTS, ALARMS

Indicating Lights

1. Switchboard #4

   Alum Truck unloading compressor

Status	Color
a. Circuit Breaker CLOSED	Amber
b. Starter CLOSED	Green

OPERATING PROBLEMS AND SOLUTIONS

Prechlorination System Malfunction

1. Indicators:
   a. Deterioration of sedimentation tank process efficiency.
   b. Large numbers of algae present in sedimentation tank effluent.
   c. Increase in backwash frequency.
2. Monitoring, Analysis, and/or Inspection:
   a. High filter effluent turbidities.
   b. Check filter effluent for algae content.
3. Corrective Measures:
   a. For mechanical failure, have equipment repaired.

b. For line blockage, try to clear line. If unable to clear, bypass line and feed prechlorination line through filter effluent chlorination line.

Insufficient Alum

1. Indicators;
    a. High flocculation chamber pH does not correspond with set alum dose.
    b. Deterioration of flocculation chamber and sedimentation tank processes.
2. Monitoring, Analysis, and/or Inspection:
    a. Check for pump malfunction.
    b. Check piping system for stoppages.
    c. Check alum storage tank level.
3. Corrective Measures:
    a. Repair alum diaphragm pump.
    b. Clear alum feed lines.

SECTION V
FLOCCULATION CHAMBER

GENERAL

The purpose of this chamber is to gently agitate the chemical and influent mixture to produce floc particles which will settle well in the sedimentation process.

OPERATION

Plant influent, containing alum and chlorine doses, enters the flocculation chamber through four 15.24 cm (6") pipes spaced 1.22 m (4 ft) apart and located 0.61 m (2 ft) above the bottom of the flocculation chamber. A pair of paddle flocculators then gently agitate the mixture and create floc particles. Detention time in this chamber is approximately 20 minutes for a design flow of 24.1 l/sec (0.55 MGD). Effluent from the flocculation chamber flows through a wooden baffle into the sedimentation tank. Influent pH and flocculation chamber pH is monitored and recorded on a circular recorder located on the Metering and Control Panel in the Control Room. A high flocculation pH reading on the recorder will cause a plant shutdown.

Equipment

An American Bowser Corporation paddle flocculator mechanism is used in the flocculation chamber. There are two paddle reel assemblies installed parallel to the chamber flow direction. These paddles are driven by a Sterling Electric Motors variable speed drive unit anchored to the top of the chamber on the east face. This unit can vary the periphial speed of the paddle reels infinitely between 0.15-0.46 m/sec (0.5 and 1.5 ft/sec.). (Normally operated at minimum speed.) Startup of the paddle flocculator may be initiated by following this sequence:

1. Starter must be ON and Circuit Breaker must be CLOSED (SWBD #4).
2. Control power is ON.

NOTE: The paddle flocculators are independent of the automatic control system and must be controlled manually.

The redwood baffle between the flocculation chamber and the sedimentation chamber reduces the turbulence in the sedimentation tank caused by the flocculator paddles. This baffle extends from the concrete separator at the bottom of the chamber to the water surface.

Chamber Dewatering

The flocculation chamber and sedimentation tank can be dewatered by opening the drain valve located two feet from the north face of the flocculation chamber at ground level. The sedimentation tank is partially dewatered at the same time (see Section VI, Sedimentation Tank Dewatering) because the upper portion of the two tanks are connected through the baffle. Both tanks will dewater until the water level reaches the top of a concrete separation wall between the two chambers. The top of this wall is the same elevation as the upper flights in the sedimentation tank.

INDICATING LIGHTS, ALARMS

Indicating Lights

1. Switchboard #4

Status	Color
Flocculator Paddle Unit Starter Closed	Green
Circuit Breaker Closed	Amber

Alarms

1. Shutdown Alarm Panel

Alarm Condition	Actuator	Location	Indicator
High pH in Flocculation Chamber	Switch on Flocculation pH Recorder	Metering & Control Panel	Red Light & Howler

OPERATING PROBLEMS AND SOLUTIONS

Flocculator Paddle Mechanism Malfunction

1. Monitoring, Analysis, and/or Inspection:
    a. Inspect mechanical equipment for failure.
    b. Inspect drive belts for slippage or loss.
2. Corrective Measures:
    a. Repair or adjust mechanical equipment.
    b. If the belts on both paddle assemblies are missing or beyond repair, dewater flocculation chamber and replace. If one paddle assembly is still operable, the plant need not be shut down for repairs until that paddle mechanism needs servicing.

SECTION VI

SEDIMENTATION TANK

GENERAL

The covered sedimentation tank contains sludge collection equipment, effluent launders, and sludge withdrawal equipment. This tank removes most of the floc particles formed in the flocculation chamber and improves the efficiency of the dual media filter.

OPERATION

Sedimentation Tank

Flow enters the sedimentation tank through the wooden baffle separating the tank from the flocculation chamber. Settleable solids and floc particles sink to the bottom of the tank and are raked to a sludge hopper at the effluent end by a chain-and-flight sludge collection mechanism. Sludge (alum sludge) is stored in the hopper before being drawn off for disposal in the plant waste sump. Sludge level in the hopper is monitored with the aid of four 2.54 cm (1") pipes located at different elevations in the hopper and lead to sample valves in the pipe gallery. Two open-channel launders, extending 4.572 m (15 ft) into the tank just below the water surface from the effluent end receive the tank effluent which flows to the dual media filter (see Figure 13).

The American Bowser sludge collection mechanism is driven from the effluent end of the tank by a 3/4 hp Olyspede electric motor. This unit has a speed reducer to allow variation of flight speeds.

1. Startup of the drive unit is not under the automatic controls and must be switched ON and OFF manually.

2. Flights should not be operated until the water level in the tank is above the guide rails.

Sludge Withdrawal

The alum sludge withdrawal system consists of a Moyno Sludge Pump or a pump bypass through a 15.24 cm (6") line from the bottom of the sludge hopper, and two 15.24 cm (6") gate valves. Sludge withdrawal from the hopper is a continuous operation except during filter backwash. Withdrawal can be performed in two ways:

1. Due to the thin consistency of the alum sludge, withdrawal can be achieved by allowing the sludge to flow by gravity to the plant waste sump, bypassing the Moyno pump. This is done when sludge flow is close to or greater than the 2.1 l/sec (33 gpm) capacity of the sludge pump. The procedure to allow gravity flow withdrawal of the alum sludge is the following:
    a. Open the 15.24 cm (6") gate valve to bypass the sludge pump.
    b. Turn sludge pump H-O-A switch OFF. (Located in pipe gallery)
    c. Close 15.24 cm (6") gate valve downstream from sludge pump discharge port.
2. The second method of sludge withdrawal is by pumping the sludge from the hopper. When alum sludge flows are low or the sludge concentration is high, this method is used. The procedure for sludge withdrawal by pumping is as follows:
    a. Open the 15.24 cm (6") gate valve downstream from the pump.
    b. Close the 15.24 cm (6") pump-bypass gate valve.
    c. Turn sludge pump H-O-A switch to AUTO.

It should be noted that the sludge pump will not run automatically unless the influent pump is running.

Sedimentation Tank Dewatering

The sedimentation tank may be dewatered to the plant waste sump by opening two 15.24 cm (6") drain valves and by pumping the sludge from the hopper. One drain valve is located at ground level just off the north face of the sedimentation tank approximately 7.62 m (25 ft) from the effluent end. The second valve is also at ground level at the north face of the flocculation chamber.

INDICATING LIGHTS, ALARMS

1. Electrical Switchboard

Status	Color
Sludge Collector Drive	
Started CLOSED	Green
Circuit Breaker CLOSED	Amber
Sludge Pump	
Starter CLOSED	Green
Circuit Breaker CLOSED	Amber

OPERATING PROBLEMS AND SOLUTIONS

Low Settleable Solids Removal Efficiency

1. Indicators:
    - a. Floating algae particles in tank.
    - b. High filter effluent turbidities.
    - c. Increase in filter backwash frequency.
2. Monitoring, Analysis, and/or Inspection:
    - a. Check chemical feed system.
    - b. Check sludge withdrawal system.
    - c. Inspect sludge collection mechanism for wear.

3. Corrective Measures:

   a. If sludge flow exceeds pump capacity, use bypass line and transfer sludge to waste sump by gravity flow.

   b. If chemical feed system malfunctions shutdown plant until repairs are made.

   c. Repair all worn sludge pump parts and sludge collection equipment.

   d. Decrease influent flow rate.

   e. Change rate of prechlorination.

SECTION VII
DUAL MEDIA FILTER

GENERAL

The Dual Media Filter removes suspended solids from the sedimentation tank effluent. Turbidity reduction in the filter unit results in a final effluent with a turbidity of less than 5.0 Jackson Turbidity Units (JTU).

OPERATION

Sedimentation tank effluent containing suspended solids and unsettled algae floc is passed through the filter bed. The disposition of solids in the bed eventually clog the filter and filtration is stopped and the bed is backwashed. Filter effluent flows by gravity from beneath the filter media through a 35.56 cm (14") pipe underdrain. (See Figure 14). The filter effluent is chlorinated and discharged to the chlorine contact chamber.

Filter media consists of a 45.7 cm (18") layer of #1-1/2 Anthracite Coal over a 22.9 cm (9") layer of #20 sand. These layers are over a 45.7 cm (18") layer of graded gravel support within which the underdrain is located. (See Table 3).

Filter effluent turbidity and the water level in the filter are monitored and recorded on circular chart recorders in the control room. A high water level (HWL) probe in the filter will shut down the plant if the backwash controls fail.

FILTER BACKWASH

The filter is backwashed with chlorinated water from the chlorine contact pond. A piping system to wash the surface of the filter media also used water from the contact pond. Backwash wastewater overflows from the filter media into the wash water channel and then flows through a 45.72 cm (18") line to the plant waste sump for disposal.

Either high effluent turbidity or high filter water level automatically start the backwash sequence. Backwash can also be initiated manually by depressing a Manual Backwash Button. The valve sequence flow control and duration of backwash as described below are the same for either a manually initiated or an automatically initiated backwash.

Backwash operation occurs in two stages. Stage I shuts down the plant and actuates the necessary valves to initiate Stage II, the actual backwashing of the filter.

Filter Backwash proceeds as follows:

Stage I

1) Influent pump STOPS.
2) Alum diaphragm pump STOPS.
3) Sludge pump STOPS.
4) Chlorinator Solenoid valve CLOSES.
5) Filter effluent valve CLOSES.
6) Filter wastewater valve OPENS.
7) Time delay (adjustable to allow excess water in the filter to drain out).

Stage II

8) Surface wash water pump STARTS.
9) Backwash throttling valve OPENS.
10) Backwash pump STARTS.
11) Surface wash water pump STOPS.
12) Backwash pump STOPS.
13) Backwash throttling valve CLOSES.
14) Filter wastewater valve CLOSES.

When the backwashing is complete the process returns to normal operation as follows:

15) Filter effluent valve OPENS.
16) Influent pump STARTS.
17) Alum diaphragm pump STARTS.
18) Sludge pump STARTS.
19) Chlorinator solenoid valve OPENS.

If a plant alarm occurs during the backwash cycle, the plant will complete its backwash cycle before shutting down.

Filter Backwash Pump

The filter backwash pump is located in the pipe gallery. Chlorinated water from the contact pond is supplied to the pump, through a 35.56 cm (14") pipe whose elevation is below the minimum water surface level of the contact pond. A Fairbanks Morse horizontal, single stage pump with a rated capacity of 205 l/sec (3250 gpm) is used for backwashing the filter. This pump is driven by a General Electric Induction Motor which produces 30 hp at 875 rpm. The pump feeds into the 35.56 cm (14") pipe at the bottom of the filter which also serves as the filter underdrain line.

Surface Washwater Pump

The surface washwater pump located in the pipe gallery is a Pacific Pumping Company pump rated at 22.7 l/sec (360 gpm) and is driven by a 20 H.P. General Electric motor. The pump takes suction from the chlorinated water in the chlorine contact pond and discharges to the surface washwater distribution system.

Backwash Throttling Valve

Flow of backwash water is controlled from the MANUAL LOADING STATION PANEL located on the walkway above the filter. The panel is equipped with a three-way solenoid valve, a pressure regulator and a manual loading regulator with a pressure gage. The valve operator is a double-acting cylinder operator with positioner which allows full control of the 30.48 cm (12") Throttling Valve. Adjustment of the backwash water flow rate can be determined by the plant operator for the bed expansion desired. The backwash rate should ensure fluidization of all the media but should not allow excessive expansion resulting in media loss. Optimum expansion will vary with type of floc and penetration of the floc into the media.

Filter Waste Sump

The backwash wastewater flows from the filter wash water channel into the plant waste sump for disposal. (See Section X, Filter Waste Sump).

INDICATING LIGHTS, ALARMS

Indicating Lights

1. Switchboard #4

Status	Color
Backwash pump	
Circuit Breaker CLOSED	Amber
Starter CLOSED	Green
Surface Wash Water Pump	
Circuit Breaker CLOSED	Amber
Starter CLOSED	Green

2. Metering and Control Panel

Status	Color
Filter Wastewater Valve OPEN	Blue
Filter Wastewater Valve CLOSED	Green
Filter Effluent Valve OPEN	Blue
Filter Effluent Valve CLOSED	Green
Backwash Throttling Valve OPEN	Blue
Backwash Throttling Valve CLOSED	Green
Backwash Sequence ON	Blue

Alarms

1. Shutdown Alarm Panel

Alarm Condition	Activator	Location	Indicator
High Filter Water Level	HWL Probe	Dual Media Filter	Plant Alarm Shutdown

OPERATING PROBLEMS AND SOLUTIONS

High Filter Effluent Turbidities

1. Indicator:
   High turbidity readings (greater than 5 JTU) on chart recorder (green pen).
2. Monitoring, Analysis, and/or Inspection.
   a. Check turbidimeter reading.
   b. Check for algae infiltration of filter media.
   c. Inspect filter influent turbidities.
3. Corrective Measures:
   a. Backwash filter more often.
   b. If euglena algae is present in large numbers, increase prechlorination dose.
   c. Decrease influent flow.

SECTION VIII

CHLORINATION SYSTEM

GENERAL

The chlorination system is provided to prevent the spread of waterborne diseases by means of chemically treating the plant effluent to kill pathogenic organisms which spread disease. The staff of the Lahontan Regional Water Quality Control Board submitted the following in the course of their investigation for waste discharge requirements.

> ..."Following the tertiary treatment processes the final effluent will be chlorinated. This chlorination is expected to provide satisfactory destruction of virus and pathogenic organisms"...

OPERATION

The chlorination system consists of chlorine unloading and storage facilities, two chlorinators, a residual analyzer, and other piping and equipment. Most of the equipment is located in the south portion of the Control Building. Chlorine lines run from the chlorine room to the effluent pumping plant and to the pipe gallery where one line chlorinates the influent and another line chlorinates the filter effluent. These two lines in the pipe gallery are interconnected so that one line can feed both systems. The final effluent chlorination line is held in reserve as a standby.

Safety Precautions for Chlorine Handling

While chlorine is no more dangerous than many of the chemicals being used in a modern wastewater treatment plant, certain procedures and precautions must be strictly adhered to in the handling of liquid and gaseous chlorine. Personnel handling chlorine must remember that chlorine is an extremely active chemical element and is toxic even in small concentrations. It is 2-1/2 times as heavy as air and is distinguished by a greenish-yellow color. It has a disagreeable, sharp, penetrating odor. Dry chlorine, at ambient temperatures, does not corrode steel or other common metals, however, in the presence of moisture it is highly corrosive and requires special construction materials for handling. Due to its combining with moisture in the respiratory tract it is a powerful respiratory irritant. In sufficient concentrations, chlorine will damage mucous membranes, the respiratory system, and skin tissue. Chlorine can be detected by its characteristic odor in concentrations as low as 3.5 parts per million (ppm). Even a 1 ppm concentration may produce slight irritation after several hours of exposure. High concentrations from 15-40 ppm promotes eye irritation and hampers the breathing process and concentrations up to 60 ppm present a health danger. A chlorine concentration of 1000 ppm will cause death after a few breaths.

When working on the chlorination system, the following precautions should be taken:

1. A standby operator should always be in attendance when loading or unloading chlorine cylinders.
2. An approved cannister type gas mask and an air mask with a self-contained air supply are stored in the Control Room, adjacent to the chlorine room. The self-contained air supply breathing apparatus shall be placed a safe distance upwind of the Chlorine Room when loading or unloading chlorine cylinders. The apparatus will be open and in a ready to use condition. This will be done prior to unloading or service operations.

3. Always look through window on Chlorine Room door before entering. See if there are signs of chlorine gas in the room. If the room appears clear, open the door, enter, and proceed to step 4.

   If the room appears contaminated, don the self-contained breathing apparatus, enter room carefully, and ventilate the room.

4. Open ALL windows, doors, and vents in the chlorine storage area.

5. Make sure the exhaust fan is running.

6. Check shower and eye bath on southwest corner of Control Building to see if operating properly.

7. The operator who will work on the chlorine system must be wearing the cannister type chlorine service gas mask. The standby operator shall at all times be in full view of the operator making or breaking pipe connections.

8. Bleed all lines of chlorine gas before servicing the unit connected to the lines.

9. In any case of difficulty or when a chlorine leak occurs, the standby operator shall immediately don the self-contained breathing unit and replace the operator making the connections.

Detection and Elimination of Chlorine Leaks

When a chlorine leak is suspected, the operator shall put on a self-contained breathing unit and investigate immediately. All other personnel must be evacuated from the immediate area of the Chlorine Room.

Remember chlorine is 2-1/2 times heavier than air and will travel with the prevailing wind and will accumulate in low spots. Keep to the UPWIND side of the chlorine leak.

To find a leak, hold a small plastic bottle filled with commercial ammonia under the suspected area and squeeze the bottle gently. In the presence of a chlorine leak a dense white cloud will be formed. DO NOT POUR AMMONIA SOLUTION ON VALVES OR PIPING. If a leak is found, shut off the chlorine valves on both sides of the leak.

1. Leaks around valve stems can usually be stopped by tightening the valve stem packing.
2. Leaks at flexible connectors: After the residual chlorine has been exhausted, tighten connecting flanges and/or replace the flange gaskets.
3. Leaks in pipe: After residual chlorine has been exhausted, replace the defective piping. DO NOT ATTEMPT TO REPAIR PIPING BY WELDING--CHLORINE AND STEEL PIPE WILL "BURN" WHEN HEATED TO 260°C (500°F).

First Aid

If chlorine liquid comes in contact with any part of the body it will cause a chemical burn. Flush affected area with water from the deluge shower or eye bath and remove contaminated clothing while under shower. If exposure is serious, call the Fire Department Rescue Squad immediately. If not so extensive, see a physician as soon as possible.

Exposure to chlorine gas will most likely affect the respiratory tract of the person. Therefore, the person's face should be deluged with water immediately to remove residual chlorine on it. The affected person should be taken from the gas area and kept as quiet as possible.

Rest is essential. A physician and the Rescue Squad should be called immediately. Serious effects may be delayed and not apparent right away.

In mild cases of throat irritation from chlorine gas, milk will give relief. Ephinephrine or ephedrine will give relief shortly after exposure when the distress is mainly from bronchial spasms. Peppermint candy can also help give relief.

Chlorine Storage

It is strongly recommended that the operator study the section on chlorine handling in the Chlorine Manual, Chlorine Institute and Fischer & Porter's booklet "Handling Chlorine Liquid and Gas from Container to Dispenser", which is included in the instruction book for the chlorination equipment. The two 1-ton cylinders and three standby 68.1 kg (150 lbs) cylinders of chlorine should be handled and stored with care.

The exchange of a full ton-cylinder on a truck or in the storage area with an empty cylinder should be performed with care. The following procedures should be performed:

1. Open all windows and doors to ensure maximum ventilation and escape route accessibility.

2. Check safety equipment availability and operation.

3. Disconnect ton-cylinder from chlorine system.

4. To replace empty cylinder with ton-cylinder held in storage:

    a. Using monorail crane and container grab, lift empty cylinder over full cylinder and set down on wooden rails next to it.

b. Now lift cylinder so that it clears the rails, move into position, and lower into place on blocks.

c. Roll or lift empty container into position evacuated by full container.

5. To replace empty cylinder with a full container from a truck:

   a. Leave operating cylinder on line.

   b. Park truck at entrance to chlorine room.

   c. Unload full container from truck utilizing truck tailgate lift.

   d. Lift empty container over new cylinder and load onto truck.

   e. Now lift full container carefully, move into position, and lower into position vacated by empty cylinder.

NOTE: Try to minimize lifting height of full containers. Dropping of the pressurized cylinder could break the casing, thereby creating an extremely hazardous situation.

Automatic Switchover

The two chlorine pressure regulators located on the north wall of the chlorine storage room, together with their piping and valves form an automatic switchover system. This system will, if properly set up, empty a ton container and automatically switch to the three standby 68.1 Kg (150 lb) cylinders. These standby cylinders would then supply the chlorination system until a full ton-cylinder is put on line.

The upper regulator is set to maintain a downstream pressure of 2.81 kg/cm^2 (40 psig), whereas the lower regulator is set to maintain a downstream pressure of 2.11 kg/cm^2 (30 psig) and will remain closed at 2.81 kg/cm^2 (40 psig). The operating container will discharge through the 2.81 kg/cm^2 (40 psig) regulator maintaining this downstream pressure until it empties. At this time, the pressure will drop and as it falls below 2.11 kg/cm^2 (30 psig), the lower pressure regulator will open and the standby cylinders will discharge to the system. When a new full ton cylinder is put on line, the standby containers automatically shut off and the ton cylinder takes over and feeds through the 2.81 kg/cm^2 (40 psig) regulator.

There are two pressure switches located downstream of the regulators. One switch will indicate on the Metering and Control Panel that the standby chlorine supply is being used. The other mercoid pressure switch will cause a shutdown alarm if the chlorine pressure drops below a pre-set minimum level, 1.41 kg/cm^2 (20 psig). This alarm can only be shut off by installing a full cylinder on line, increasing the line pressure.

Chlorinators

Two Fischer and Porter Series 70-3660 Solution feed gas dispensers are used to feed gas at a manually controlled rate to the ejector water supply. One chlorinator feeds the prechlorination line to the plant influent and the other chlorinator feeds the filter effluent or final effluent chlorination lines, whichever is in service. This chlorination system is capable of supplying 45.40 kg (100 lbs) of chlorine gas per day.

The potable water supply feeding the chlorinators is connected to a mercoid switch and solenoid valve. This solenoid valve shuts off the chlorination system during backwashes and plant alarm shutdowns. The mercoid switch shuts down the plant if the water pressure drops below an adjusted lower limit.

Residual Chlorine Analyzer

A residual chlorine analyzer located in the Control Room, monitors the chlorine residual in the final effluent leaving the plant and records the values obtained on a chart recorder in the Metering and Control Panel.

Chlorine Contact Chamber

The chlorine contact chamber provides a detention time of 8-10 hours at design flow. This chamber is fed by a 30.48cm (12") line discharging at the bottom of the east end of the tank. Washwater is supplied to the tertiary plant through a 35.56 cm (14") pipe whose inlet is near the northwest corner of the chamber. Probes in the Effluent Pump wetwell control high and low water levels in the contact chamber. A 45.7 cm (18") pipe near the bottom of the chamber on the west face is used to transfer chlorinated water to the wet well of the effluent pumping station. There is a drain sump at the bottom of the northwest corner which is used to dewater the chamber. Water from this sump goes directly to the influent wetwell for the District 14 plant. This drain sump is also used to dispose of water which does not meet the effluent quality criteria.

INDICATING LIGHTS, ALARMS

Indicating Lights

Status	Color	Location
Standby Chlorine on line	Red	M & C Panel
Chlorinator OFF	Red	M & C Panel
HWL In Chlorine Contact Chamber	Red	Shutdown Alarm Panel
Chlorine Cylinders Empty	Red	Shutdown Alarm Panel
Low Chlorine Residual	Red	Shutdown Alarm Panel

Shutdown Alarms

Alarm Condition	Actuator	Location
Low Chlorine Line Pressure	2 Mercoid Switches	Chlorine Room
Low Chlorine Residual	Contact on Residual Recorder	M & C Panel
HWL in Chlorine Contact Chamber	HWL Probe	Contact Chamber

OPERATING PROBLEMS AND SOLUTIONS

This section covers some of the more common operating problems which may occur periodically and prevent the chlorination system from operating in a normal fashion. When a problem occurs which reduces the quality of tertiary plant effluent, the facility should be shut down until repairs are made or until a backup system is put on line.

Insufficient Chlorinator Gas Pressure

1. Indicators:
    a. Chlorine pressure gauge at chlorinator is reading too low.
    b. Chlorine supply lines from containers are either very cold or are icing.
    c. There is icing or considerable cooling at one point in the chlorine header system between the container and the chlorinator.
2. Monitoring, Analysis, and/or Inspection:
    a. Reduce feed rate on chlorinator to one-tenth the rotometer capacity.
    b. If icing condition or cooling effect does not disappear, mark the point where cooling begins and secure the chlorine supply system at the containers, but let the chlorinator continue to operate.

3. Corrective Measures:
   a. When chlorine gas pressure at the chlorinator reaches zero and with chlorinator still operating, disconnect flexible connection to the primary chlorine feed container. (This will allow chlorinator to evacuate residual chlorine in header system by replacing with air.)
   b. Disassemble chlorine header system at point where cooling began. A stoppage or a flow restriction will be found, at or near this point.
   c. After the stoppage has been found, it can be cleaned with a solvent such as tri-chlorethylene.
   d. For a massive buildup in the piping system, the pickling process should be used. This consists of isolating the header system by disconnecting it from both the feed cylinder and the chlorinators, and flushing with cold water until the water coming out is clear, the header then has to be dried with steam or hot air and final air drying to a dew point of -40°C (-40°F).

No Chlorine Gas Pressure With an Apparently Full Chlorine Container

1. Indicators:
   Chlorinator gas pressure gauge is at zero, inlet valve is open, all valves, beginning with the chlorine container valve to the chlorinator are open.

2. Monitoring, Analysis, and/or Inspection:
   a. If normal chlorine pressure appears at the

chlorinator, secure the main chlorine container valves and open all windows, and doors to ensure maximum ventilation.

   b. Put on the cannister gas mask and gingerly break one flexible connection joint to release the gas in the header system.
   c. Place a bottle of ammonia on the floor near the floor near the connection to be broken and when a white vapor appears, leave the area as quickly as possible and return only when the vapor disappears.
   d. Repair the reducing valve which is probably plugged from the inherent impurities in chlorine gas.

3. Corrective Measures:
   Check the external chlorine pressure reducing valve downstream from the chlorine container.

No Chlorine Fed with All Systems Appearing Normal

1. Indicators:
   a. Chlorinator feed rate indicator shows little or no indication of chlorine flow when chlorine control valve is moved from closed to wide open position.
   b. The chlorine pressure gauge in the chlorinator is normal, but the injector vacuum gauge shows an abnormally high vacuum.

2. Monitoring, Analysis, and/or Inspection:
   Check for an obstruction in the chlorine gas line near or at the inlet cartridge of the chlorine pressure reducing valve inside the chlorinator by shutting off the chlorine supply at the chlorinator. Chlorine pressure gauge remains the same or moves

downward in pressure at a very slow rate, i.e., one division per five minutes.

3. Corrective Measures:
   a. Shut off chlorine supply at the container and try to let the chlorinator drain off all the chlorine gas pressure in the chlorine supply line.
   b. If this cannot be done, make sure the chlorine cylinder is secure, provide maximum ventilation to the chlorine room, put on a gas mask, and break a connection in the chlorine supply header.
   c. When the gas has sufficiently cleared itself from the working area, disassemble the chlorinator pressure reducing valve to remove inlet cartridge and clean stem and seat with a soft cloth.
   d. If this situation occurs regularly during hot weather, the source of the trouble usually is a result of the chlorine cylinders being hotter than the chlorine control apparatus.
   e. Inspect cylinder area to see if anything can be done to make the area cooler.
   f. Do not connect a new cylinder if it has been allowed to sit in the sun.

Chlorine Gas Leaking from Vent Line

1. Indicators:
   a. There is no visible indication of a malfunction.
   b. Chlorine escaping from CPRV vent line.
   c. Chlorine gas pressure, chlorine feed rate, and injector vacuum are all normal.

2. Monitoring, Analysis, and/or Inspection: Confirm leak by placing ammonia bottle near the termination of the CPRV vent line.

3. Corrective Measures:
   a. The symptom described indicates that the main diaphragm of the CPRV has been ruptured.
   b. Remove the external CPRV after evacuating header system, disassemble valve and replace diaphragm.
   c. Inspect the ruptured diaphragm to see if failure is from corrosion, improper assembly, or just fatigue from length of service.
   d. Consult manufacturer for expert opinion.
   e. If failure is from corrosion the chlorine supply system should be inspected for moisture intrusion.

Inability to Obtain Proper Feed Rate from Chlorinator

1. Indicators:
   a. With chlorinator in manual control and the chlorine control valve is manipulated to vary the feed rate, the change of feed rate response seems sluggish and chlorinator will not achieve maximum feed rate.
   b. The injector vacuum reading is borderline, and when feed rate is reduced the injector vacuum does not increase appreciably.

2. Monitoring, Analysis, and/or Inspection:
   a. Check the chlorinator vent system for a small vacuum leak in the chlorine control apparatus by disconnecting the vent line at the chlorinator and while observing the chlorinator operation (feed rate and injector vacuum), place a hand over a vent connection to the vacuum

relief device on the chlorinator. If this action produces more injector vacuum and more chlorine feed rate, it signifies that air is entering the chlorinator via this mechanism (vacuum relief device) due to weak springs from normal metal fatigue.

   b. Moisten all joints to a vacuum with ammonia solution or put paper impregnated with orthatolidine at each of these joints. With the chlorinator operating at maximum feed rate, close the injector discharge line as rapidly as possible. If there is a vacuum leak in the chlorinator system it will be detected by either the ammonia or the paper.

3. Corrective Measures:
   a. If the vacuum leak is in the vacuum relief device, disassemble mechanism and replace all springs.
   b. Repair all other vacuum leaks by tightening a joint, replacing gaskets, tubing, and/or compression nuts.

Insufficient Feed to Produce Proper Chlorine Residual

1. Indicators:
   The chlorine residual chart will show periods during the day of insufficient chlorine residual.
2. Monitoring, Analysis, and/or Inspection:
   a. By manual control test the chlorinator to see if it will pull maximum feed rate.
   b. Determine if solids have settled to the bottom of the contact chamber.
3. Corrective Measures:
   a. If needed, clean the chlorine contact chamber.

SECTION IX
EFFLUENT PUMP STATION

GENERAL

The purpose of this station is to pump product water from the tertiary plant to the Apollo Park recreational area.

OPERATION

Chlorine contact chamber water flows into the pump wetwell at the west end of the chamber through a 45.72 cm (18") pipe and slide gate. One of the two effluent pumps is used to draw water from the wetwell and pump tertiary plant effluent about 7.24 Km (4½ mi) through a 30.48 cm (12") force main to the recreational lakes. A sample line connection and chlorine injection point are located just downstream from the wye joint used to discharge effluent flows from each pump into a common 20.32 cm (8") line for ultimate discharge into the 12" force main.

Effluent Pump #1 is a Peerless, 2-stage, vertical turbine, water lubricated pump capable of pumping 23.66 l/sec (375 gpm or 0.54 mgd) at a total head of 18.3 m (60 ft). Effluent Pump #2 is a Peerless, 2-stage, vertical turbine, water lubricated pump capable of pumping 47.30 l/sec (750 gpm or 1.1 mgd) at a total head of 25.9 m (85 ft).

Pump #1 was installed to handle Stage I flows and Pump #2 to handle the increased flows of Stage II expansion. The units are controlled so that only one of the pumps can operate under the automatic circuit at any given time. The second pump can be operated in addition to the first pump, but only under manual control.

Startup Procedure for Effluent Pump #1:

1. Slide gate at wet sump must be open to allow chlorine contact pond water to enter the wet well.

CAUTION: EFFLUENT PUMPS MUST NOT BE OPERATED WHEN SUMP IS DRY!

2. Open 20.32 cm (8") gate valve between Pump #1 and the wye junction.
3. Starter Switch must be ON.
4. Circuit Breaker must be CLOSED.
5. Set automatic pump selector on switchboard panel in Control Room to Effluent Pump #1 or Pump #2.
6. Turn H-O-A Switch to AUTO.

To start control for the operating pump is a Probe in the wet well chamber and the stop control is the LWL Probe.

INDICATING LIGHTS, ALARMS

Indicating Lights

1. Electrical Switchboard

Status	Color
Pumps 1 and 2	
Circuit Breaker CLOSED	Amber
Starter CLOSED	Green

Shutdown Alarm

Activator	Alarm
HWL in pump wet well	Red

SECTION X

FILTER WASTE SUMP

GENERAL

The primary purpose for this sump is to serve as a surge chamber for the filter backwash water. It also receives the alum sludge waste from the sedimentation tank hopper. The sump is concrete lined and has a capacity of 94.6 m^3 (25,000 gallons).

OPERATION

The sump and connecting piping serve as a gravity drain which meters the flow to the influent pump wet well of the District 14 Primary Plant.

SECTION XI

PIPE GALLERY SUMP

GENERAL

The pipe gallery sump collects drainage from the sampling lines and from the pipe gallery floor.

OPERATION

Wastewater from the pipe gallery drains into the sump. When the liquid level in this sump reaches a predetermined elevation, the Probe activates the sump pump which discharges gallery wastewater to the plant waste sump. A LWL Probe shuts the pump off. To put the sump pump on line, the following procedure must be performed:

1. Turn Starter switch on SWBD #4 to ON.
2. CLOSE Circuit Breaker.
3. Turn H-O-A switch in pipe gallery to AUTO.

INDICATING LIGHTS, ALARMS

Indicating Lights

Status	Color
Circuit Breaker CLOSED	Amber
Starter CLOSED	Green

Alarms - Plant Shutdown

HWL in gallery sump	Red

SECTION XII

INSTRUMENT AIR COMPRESSOR

GENERAL

The air from this compressor unit operates pneumatic valves and instrument recorders.

OPERATION

The compressor is a Bell and Gossett "Oil-less" unit mounted on a 60-gallon air tank and is equipped with an air dryer unit. The air supply which operates the following units is normally maintained at 6.33-7.38 kg/cm^2 (90-105 psig).

1. Filter Backwash Throttling Valve.
2. Filter Effluent Valve.
3. Filter Wastewater Valve.
4. Turbidity, pH, and Filter Headloss Chart Recorders.
5. Alum Manometer.

Startup for Air Compressor:

1. CLOSE Circuit Breaker on SWBD #4.
2. Turn Starter switch to ON.
3. Turn H-O-A switch in pipe gallery to AUTO.

INDICATING LIGHTS

Status	Color
Circuit Breaker CLOSED	Amber
Starter CLOSED	Green

SECTION XIII
INSTRUMENTATION

GENERAL

This instrumentation system includes the Metering and Control Panel, the Shutdown Alarm Panel, Electrical Switchboard, and various field mounted meters and controls. These systems monitor and/or control plant operations.

OPERATION

Instrumentation for the tertiary treatment plant can be divided into three sections: (1) Indicating and Recording Instruments, (2) Controls on Individual Equipment; and (3) Shutdown Alarm Panel System. These three sections are shown in tabular form in Tables 4, 5, and 6 (Pgs 37-41) and summarized as follows:

Table 4 (Indicating and Recording Instruments) lists various instruments, their function, the primary instrument location and type, and the indicator or recorder location.

Table 5 (Controls on Individual Equipment) shows, in tabular form the various units in the tertiary process, the type of switch used, start and stop controls, and start-up interlocks.

Table 6 (Shutdown Alarm Panel) summarizes the alarms and sensing instruments which control automatic plant shutdown. When an alarm is sounded, a red light on the Shutdown Alarm Panel indicates, and the alarm horn sounds outside the Control Building. The alarms can be silenced by depressing the warning light switch. The red light will continue to glow, however, until the alarm condition is corrected. With the exception of the Low Chlorine Supply Pressure Alarm, the shutdown alarms can be locked-out of the system to eliminate the nuisance of audible alarms during maintenance or plant startup.

The Plant Control and Alarm System operates the plant automatically by performing the following three major operations:

1. Normal Operation - Plant is producing treated water.
2. Backwash Operation - Filter bed is being backwashed.
3. Plant Shutdown Operation - manual shutdown or automatic alarm shutdown.

The following is a description of these three operations:

Normal Operation

The plant is producing treated water.

Backwash Operation

The filter bed backwash is initiated by one of the following controls:

1. High turbidity contact on effluent turbidity meter.
2. High water level contact on filter water level recorder.
3. Manual initiation.

Filter backwash proceeds as follows:

Stage I

1. Influent pump STOPS.
2. Alum diaphragm pump STOPS.
3. Sludge pump STOPS.
4. Chlorinator solenoid valve CLOSES.
5. Filter effluent valve CLOSES.

6. Filter waste water valve OPENS.

7. Time delay (adjustable to allow excess water in the filter to drain out).

Stage II

8. Surface wash water pump STARTS.

9. Backwash throttling valve OPENS.

10. Backwash pump STARTS

11. Surface washwater pump STOPS.

12. Backwash pump STOPS.

13. Backwash throttling valve CLOSES.

14. Filter wastewater valve CLOSES.

Process then returns to Normal Operation as follows:

1. Filter effluent valve OPENS.
2. Influent pump STARTS.
3. Alum diaphragm pump STARTS.
4. Sludge pump STARTS.
5. Chlorinator solenoid valve OPENS.

Plant Shutdown

Either manual or automatic alarm shutdown proceeds as follows:

1. Influent pump STOPS.
2. Alum diaphragm pump STOPS.
3. Sludge pump STOPS.
4. Chlorinator solenoid valve CLOSES.

Special Conditions Governing Operational Sequences

1. Each time the INFLUENT PUMP STARTS, a timer LOCKS-OUT the high turbidity backwash initiating control signal for an adjustable time period (0-30 Min.).

2. If a plant alarm occurs DURING the backwash cycle, the plant will complete its backwash cycle before shutting down.

3. The Backwash Pump and Influent Pumps run ALTERNATELY, except after plant shutdown when an electrical interlock relay returns to the "Backwash" position. Automatic startup of the Influent Pump cannot occur until this interlocking relay is manually reset to the Influent Pump position. (This interlock can also be reset to the Influent Pump position by manually turning the main Backwash Pump H-O-A switch to the HAND position momentarily)

4. The Influent Pump WILL NOT RUN automatically unless the following conditions are satisfied:
    a. Filter Wastewater and Backwash Throttling Valves must be CLOSED.
    b. Filter Effluent Valves must be OPEN.

5. The Sludge and Alum Pumps will NOT RUN automatically and the Chlorinator Solenoid Valve will NOT OPERATE unless the Influent Pump is RUNNING.

6. The Backwash Pump WILL NOT RUN automatically unless the following conditions are met:
    a. Filter wastewater and Backwash Throttling Valves must be OPEN.
    b. Filter Effluent Valve must be CLOSED.

SECTION XIV

SAMPLE COLLECTION AND LAB ANALYSIS

GENERAL

The Tertiary Plant is equipped with instrumentation which constantly monitors and records the treatment plant operations. This instrumentation system controls the plant and is programed to automatically shut down the entire tertiary treatment plant if the treated water does not meet the required quality standards. Even though the instruments performing these monitoring and control functions are highly reliable their performance must be checked by analyzing concurrent samples. The plant operator also does routine sampling and laboratory analysis for other constituents, including phosphate and suspended solids which are not monitored by the instrumentation system.

SAMPLING AND TESTING

The plant operator is encouraged to read Standard Methods for the Examination of Water and Waste Water for a better understanding of the laboratory tests listed below:

Total Phosphates
Suspended Solids
Chlorine Residual
pH
Ammonia Nitrogen

The recommended laboratory procedures for performing these tests are summarized on the following pages.

Total Phosphate Digestion Procedure

1. All glassware must be washed with hot dilute HCI and rinsed with distilled water prior to use.
2. Place 100 ml or a suitable aliquot of sample diluted to 100 ml in a 125 ml erlenmeyer flask.
3. Add one drop of phenolphthalein soln. Neutralize by discharging the red color if necessary with sulfuric acid soln.
4. Add 1 ml sulfuric acid soln in excess.
5. Add 15 ml potassium persulfate soln. (Make fresh daily.)
6. Boil gently for 90 minutes adding distilled water to keep the volume between 25 and 50 ml.
7. Cool and add one drop of phenolphthalein soln, then neutralize to faint pink color with sodium hydroxide soln.
8. Restore the volume to 100 ml with distilled water.
9. Proceed with Stannous Chloride Method for low phosphates, or with the Vanadomolybdophosphoric Acid Method for high phosphates. Start at step No. 4.

Reagents:

Phenolphthalein Indicator Solution - Dissolve 5 g phenolphthalein in 500 ml 95% isopropyl alcohol and add 500 ml distilled water.

Sulfuric Acid Solution - Carefully add 300 ml conc. H_2SO_4 to 600 ml of distilled water and dilute to 1 liter with distilled water.

Potassium Persulfate Solution - Dissolve 5 g of potassium persulfate in 100 ml of water.

Sodium Hydroxide Solution - Dissolve 40g of sodium hydroxide and dilute to 1 liter with distilled H_2O

Ref. p. 526, 13th ed. Standard Methods

High Phosphate Determination
Vanadomolybdophosphoric Acid Method

1. For total phosphate determination go through preliminary digestion procedure. For ortho-phosphate determination proceed as follows:
2. All glassware must be washed with hot dilute HCl and rinsed with distilled water prior to use.
3. If pH is less than 4, dilute 40 ml of sample to 100 ml. If pH is greater than 10 add 1 drop phenlphtolein solution to 50 ml sample and discharge color with concentrated HCl, then dilute to 100 ml.
4. Pipet 35 ml or suitable aliquot into a 50 ml volumetric flask.
5. Add 10 ml vanadate-reagent and dilute to mark with distilled water.
6. Read at 400 mμ after 10 minutes.

Reagents:

Vanadate-reagent

Solution A. Dissolve 25g ammonium molybdate in 400 ml distilled water.

Solution B. Dissolve 1.25 g ammonium meta vanadate by heating to boiling in 300 ml distilled water, and letting it boil down to 200 ml. Cool and add 330 ml HCL concentrate.

When cool pour solution A into solution B and dilute to 1 liter.

Low Phosphate Determination
Stannous Chloride Method

1. For total phosphate determination go through preliminary digestion procedure. For ortho-phosphate determination proceed as follows:

2. All glassware must be washed with hot dilute HCl and rinsed with distilled water prior to use.

3. Add 1 drop of phenolphtholein solution to a 100 ml sample or aliquot diluted to 100 ml. Neutralize by discharging the red color with strong acid solution. If more than five drops are needed take a smaller aliquot and dilute to 100 ml, after first discharging the pink color.

4. To the 100 ml sample add 4.0 ml molybdate reagent and mix (be sure reagents and samples are the same temperature).

5. Add 0.5 ml (10 drops) stannous chloride reagent and mix.

6. After 10 minutes and before 12 minutes measure photometrically at 690 mu.

Reagents

Strong Acid Solution - Slowly add 300 ml concentrated H_2SO_4 to 600 ml distilled water. When cool add 4.0 ml concentrated HNO_3 and dilute to 1 liter.

Ammonium Molybdate Reagent - Dissolve 25 g ammonium molybdate $(NH_4)_6 - Mo_7 O_{24} \cdot 4H_2O$ in 175 ml distilled water. Cautiously add 280 ml concentrated H_2SO_4 to 400 ml distilled water, cool and add the molybdate solution and dilute to 1 liter.

Stannous Chloride Reagent - Dissolve 2.5g of fresh stannous chloride ($SnCl_2 \cdot 2H_2O$) in 100 ml glycerol. Heat in a water bath and stir with glass rod to hasten dissolution.

Ref. pp 530-532 - 13th ed. Standard Methods

Suspended Solids Tests

1. Pour a well mixed aliquot of sample into a graduate, allowing for settling, depending on type of sample.
2. Place dried-washed, pre-weighed filter on filter-holder.
3. Pour sample on filter. (Amount of sample depends on type of sample, i.e. raw, primary and secondary)
4. Turn on vacuum.
5. Rince graduated cylinder with distilled water and pour on filter, after all sample has been poured.
6. Rinse down sides of holder with distilled water.
7. Remove filter holder containing suspended solids carefully.
8. Place filter in petri dish, allow to air dry for 15 - 20 mins.
9. Place filter, uncovered, in oven (103°C) for one hour.
10. Remove petri dish with S.S. from oven, cover and weigh within 1/2 hour.

Note: All millipore filters should be distilled, washed, dried for 30 - 40 min. and kept in desication until weighed.

Chlorine Residual - (Back Titration)

Iodometric

1. Pipet 5 ml phenylarsine oxide solution, 0.00564N. into 500 ml erlenmeyer flask.
2. Add 4 ml pH 4.0 (Acetate buffer solution).
3. Add @ 1 gm potassium iodide crystals to flask.
4. Pipet 200 ml sample into flask.
5. Start mixing with magnetic stir.
6. Add @ 1 ml starch solution.
7. Titrate with iodine, 0.0282 N. to first appearance of blue color which persists after complete mixing.

Reagents:

1. Standard Iodine Solution, 0.1N:
    a. Dissolve 40 gm KI in 25 ml distilled water, add 13 g resublimed iodine, and stir until dissolved.
    b. Transfer to 1-liter volumetric flask and dilute to mark.
2. Standard Iodine Titrant, 0.0282 N:
    a. Dissolve 25 g KI in distilled water in a 1-liter volumetric flask.
    b. Add the proper amount of 0.1 N iodine (282 ml/liter) solution exactly standardized to yield a 0.0282 N solution and dilute to 1-liter.
    c. Store in amber bottles or in the dark, and keeping it from all contact with rubber.

3. Acetate Buffer Solution, pH 4.0:
   a. Dissolve 146 g anydrous $NaC_2H_3O_2 \cdot 3\ H_2O$ in 400 ml distilled water, add 480 g Concentrated acetate acid, and dilute to 1-liter with distilled water.

4. Starch Solution:
   See Standard Method, pp. 377.

Calculation:

$$\text{mg/l Cl} = \frac{(A-5B) \times 200}{C = \text{Sample size}} \quad \text{OR}$$

$$5 - \underline{(5 \times \text{titration})} = \text{Cl}$$

A = ml 0.00564 N reagent

B = ml 0.0282 N I. and C = ml sample.

See Standard Method, pp. 377.

pH Value:

The practical pH scale extends from 0, very acidic to 14, very alkaline, with the middle value (pH 7) at 25°C.

1. Adjust pH meter to 7.0 with standard buffer. Set temperature control at ambient temperature. If solution is not on cold, adjust the temperature accordingly.
2. Pour a thoroughly mixed sample into a small beaker.
3. Remove electrodes from distilled water, and wipe with soft tissue.
4. Carefully immerge electrodes into sample, mix, read and turn off.

5. Remove electrodes from sample. Remove any film from electrode with proper solvent or a mild detergent, using soft tissue and being careful to wipe away all the film. Rinse again with distilled water.

6. Always keep both electrodes immersed in distilled water when not in use.

See Standard Methods, pp. 422

Ammonia Nitrogen (NH_3)
(Distillation Method - Modified)

1. Place 100 ml of raw sewage or 200 ml effluent into a 650 ml Kjeldahl flask.

2. Add 25 ml of phosphate buffer (pH @ 7.4).

3. Add 2 boiling chips and pinch of 'Fishers' bath wax to prevent from boiling over.

4. Dilute to 400 mls (For samples containing more than 250 mg/l calcium, add 40 ml of buffer first, then adjust pH to 7.4 with acid or base).

5. Place a 500 ml Erlenmeyer flask containing 50 ml of boric-acid solution indicator at the receiving end of condenser. The tip should extend below the surface of the indicator.

6. Connect the Kjeldahl flask to the apparatus.

7. Turn on cooling water. Set desired temperature; (Be cautious to avoid overheating and foaming).

8. Distill until 200-300 ml of distillate has been collected.

9. Lower receiving flask from stand to prevent loss of sample. Turn off heat.

10. Remove flask when cooled. Titrate with 0.02 N H_2SO_4 to a lavender color.

11. Calculation:

$$\text{mg/l } NH_3\text{-N} = \frac{\text{ml titr. x 280}}{\text{sample size}}$$

Or: Factor x Titration:

Example: 200 ml sample = 1.4 x titration

100 ml sample = 2.8 x titration

Ref: Standard Methods, pp. 391-392, 1965 edition

Preparation of Reagents:

1. Phosphate Buffer Solution, 0.5M:
Caution: Before adding chemicals for preparation for solution, make certain that dilution water is agitating, to prevent crystallization of chemicals. Dissolve 14.3 gm. anhydrous potassium dihydrogen phosphate, KH_2PO_4, and 66.8 gm anhydrous dipotassium hydrogen phosphate, K_2HPO_4, in ammonia-free water and dilute to 1-liter, producing a pH 7.4.

2. Indicating Boric Acid Solution:
Dissolve 20 gm boric acid, H_3BO_3 in water. Add 10 ml mixed indicator, dilute to 1-liter. Solution must be made fresh every 30 days.

3. Mixed Indicator:
Dissolve 0.2 gm methyl medium into 100 ml of ethyl alcohol.

Dissolve 0.2 gm methylene blue into 100 ml of ethyl alcohol.

This solution must be made fresh every 30 days.

4. Standard Sulfuric acid titrant:
Pipet 0.6 ml conc H_2SO_4 into 1-liter of distilled water. Normality should be @0.0200 N. A standard acid solution, exactly 0.0200 N, is equivalent to 1.00 mg $CaCO_3$ per 1.00 ml.

Ref: Standard Methods, 1965 edition pp. 391-392

SECTION XV

PREVENTIVE MAINTENANCE

PURPOSE

A comprehensive preventive maintenance program is an essential part of plant operations. It will ensure longer and better equipment performance than equipment that is given little, if any, care. The following paragraphs are to be used as guidelines in performing the required maintenance on the plant equipment. The information about the various units was taken from the manufacturer's manuals or other acceptable material on equipment maintenance.

SCOPE

The information on the equipment maintenance is for preventive maintenance only; routine greasing, oil changes, and cleaning of the equipment. For major repair and/or overhaul the manufacturers' manual should be consulted.

This section will not include work on instrumentation. That work is left to the instrument technicians, who are trained and qualified for that type of work. The section on the chlorination equipment is only for cleaning that is required for good operation.

If any questions arise concerning the equipment, the manufacturers' manuals should be consulted.

A list of oil and grease is attached at the end of this section.

PREVENTIVE MAINTENANCE LOG

Any work that is done to a piece of equipment should be logged in the log book for that unit. The date, work done, part numbers, any parts replaced, and initials of the individual doing the work should be entered.

PUMPS

This section includes all pumps in the plant and their related equipment. If special attention is required on a specific unit at a prescribed maintenance interval, that unit will be named Influent Pump, etc., otherwise, it will fall into the general pump category.

Grease and Oil

The proper grade of grease or oil is a necessity. If it is too thin or thick it will impede proper functioning of bearings and gears. See attached list of grease and oil.

The drain, or relief, plug should be removed during greasing of bearings or couplings. This allows the old grease to be removed and relieves excessive pressure built up inside the bearing. This plug should be left out for approximately 10 minutes. If there is no drain plug the lubrication fitting should be removed to relieve internal pressure on the bearing. More damage is done to bearings by overgreasing than under greasing.

Packing

The packing of a pump is very important. Its function is to seal the pump while allowing some shaft deflection. Water or grease is used to lubricate the packing so it is very important that the sealing fluid is maintained in the proper quantities. The packing size is very important. Do not try to use larger or smaller packing. The larger packing will cause overheating and very rapid wear to the shaft or sleeve and small packing will not seal.

The packing gland will have to be adjusted periodically. The gland should be tightened slowly, about 1/4 turn on the adjusting nut. This allows the packing to start seating properly without being burned. Packing should never be tightened and then left. The adjustment may be too tight, burning the packing and possibly causing damage to the pump shaft or shaft sleeve. Leakage of water should be the smallest possible steady stream.

When packing gland leakage is excessive and cannot be controlled by tightening the adjusting nuts, the pump must be repacked. This is done by removing the packing gland and removing all the old packing. The lantern ring must be removed to get the final rings of packing. Be sure to insert the correct number of rings below the lantern ring and then insert the ring and the rest of the packing. It is necessary for the lantern ring to be in the proper place so the sealing fluid, water or grease, can get into the packing.

Cleanup

After performing routine maintenance, the unit should be wiped down, removing any oil or grease. Cleanup any mess on the floors and throw away the rags or waste used for cleaning.

Preventive Maintenance

Check pumps and auxiliary equipment daily for the following:

1. Noise
2. Vibration
3. Packing gland leakage
4. Bearing temperatures
5. Oil or grease leaks
6. Hot spots
7. Packing gland drain line clear
8. Sump clear of large debris
9. Alum pump oil level

Weekly perform the following:

1. Wipe off all equipment.

Quarterly perform the following:

1. Grease influent pump
2. Keep grease cups full on effluent pumps
3. Check drive belts on alum pump and adjust if necessary.

Annually perform the following:

1. Oil alum diaphragm pump motor
2. Change oil in alum diaphragm pump
3. Check bearings on alum pump
4. Grease all other pump motors
5. Grease varidrives on influent and sludge pumps
6. Change oil in sludge pump gear reducer
7. Grease backwash pump

As necessary, perform the following:

1. Paint the equipment

PADDLE FLOCCULATION MECHANISM

Daily, check the following:

1. Noise
2. Vibration
3. Drive belts

Quarterly, perform the following:

1. Check oil level in speed reducer

Semi-Annually, perform the following:

1. Change oil in speed reducer.

As necessary, perform the following:

1. If chamber is dewatered, grease shaft bearings
2. Adjust drive belts

SLUDGE COLLECTION MECHANISM

Daily, check the following:

1. Noise
2. Vibration
3. Oil Leaks
4. Idler sprocket

Weekly, perform the following:

1. Check oil in gear reducer

Quarterly, perform the following:

1. Grease bearings

Semi-Annually, perform the following:

1. Grease drive end of gear reducer.
2. Grease shear pin sprockets in drive assembly
3. Change oil in gear reducer

As necessary, perform the following:

1. If tank is taken out of service, grease submerged bearings and inspect flights and chains.
2. Adjust chains

CHLORINATION SYSTEM

When working on any part of the chlorine system, extreme care must be used. Exposure to chlorine could result in serious injury or death. Be sure to read the instruction bulletins on chlorine handling recommended in the Operations Section of the Chlorination System.

Daily, check the following:

1. Buffer reagent in analyzer
2. Proper flow through the head control of the analyzer.
3. Calibration of chlorine analyzer
4. Chlorine heaters are working

5. Chlorine gas pressure
6. Water pressure to chlorinators
7. Vacuum on chlorinators

As necessary, perform the following:

1. Gas dispenser
    a. Clean flowmeter
    b. Clean flowrater valve
    c. Clean vacuum stabilizing valve
    d. Clean vacuum relief valve
    e. Clean drain valve
    f. Clean ejector
    g. Clean traps on the chlorinators and on the gas feed lines.
2. Clean water strainer

VENT FANS

Daily, check the following:

1. Noise
2. Vibration

ALUM UNLOADING COMPRESSOR

When Operating, Check the following:

1. Noises
2. Vibration
3. Oil leaks
4. Oil level in reservoir

Annually, perform the following:

1. Change oil
2. Grease motor

OIL AND GREASE LIST

Use Union Oil Red Line Turbine 1000 or the equivalent and No. 2 bearing grease.

SECTION XVI

EMERGENCY OPERATING CONDITIONS AND RESPONSE PLANS

GENERAL

The information presented in this section is designed to aid the operator in answering emergencies; however, it should be remembered that the operator is usually the one who assesses the situation as it occurs. In most cases, responding to the situation does not have to be immediate since the process will not deteriorate immediately. This gives the operator on duty the chance to assess the situation, decide on the course to follow and then carry out the plans in an orderly, controlled manner. Therefore, should the operator feel that a change in procedure is justified due to the events as they happened, he should make the changes required.

EMERGENCY WARNING EQUIPMENT

General

Shutdown alarms are located on the Shutdown Alarm Panel in the Control Room. Should any of the alarms be actuated due to a malfunction, a horn and/or light will audibly and visually indicate the alarm condition. In this event, the operator should immediately answer the alarm condition and determine its cause.

Response to Alarm Conditions

1. Proceed to the Control Building and determine the cause of the alarm.
2. Silence the alarm by pushing the red light on the shutdown alarm panel.
3. Determine the cause of the failure and correct, if possible. If the procedure required to correct the alarm condition is too extensive to be handled

by the personnel on hand, shut plant down and notify your supervisor.

POWER FAILURE

In the event power is lost to the entire plant, the following should be followed:

1. Call Southern California Edison Company at (805) 942-9531 and inform them of the failure. At the same time request an estimate of the length of time power will be lost to the plant.
2. Any power outages should be logged on the Monthly Summary of Operation Sheets and in the plant Log Book.

In the event of power failure to any individual piece of equipment in the plant, the following procedure should be followed:

1. Throw the circuit breaker for the faulty piece of equipment to the "OFF" position.
2. Shut down plant
3. Notify supervisor and Districts electricians of the malfunction.
4. Under no circumstances should the operator attempt to repair an electrical failure within the plant.
5. The operator should be present when the electrician arrives and inform him of any events which could possibly have led to this failure.

EARTHQUAKE

General

In the event of an occurance of this type, there is nothing the operator can do while the quake is happening, save protect himself from injury. However, once the quake has subsided, there are certain procedures which should be followed. These consist of checking the plant for damages and restarting equipment where necessary.

Inspection Procedures

The following items should be inspected for damage and reported:

1. All structures, buildings, tanks, galleries, etc. should be checked for structural damage.
2. Check all machinery for damage or realignment which could have occurred during the quake. Especially check the mountings of all heavy machinery for cracks and broken bolts which could allow the equipment to shift or break loose during normal running.
3. After the equipment and structures have been visibly checked and appear to be undamaged, restart any equipment which was shut down due to the quake.
4. Chlorination facilities should be checked very closely for any leaks.
5. Check all piping for leaks and damage.
6. If any equipment will not operate, shut down plant until repairs can be made.

FIRE

In the event of fire, the operator should assess the severity and type of fire. The Fire Department should then be notified immediately at (805) 948-2631. Fire fighting equipment good for any type of fire has been provided throughout the plant for use in extinguishing fires, or preventing the spread of fires. In the event a fire cannot be extinguished by plant personnel, the following general procedures should be followed to prevent further spread of the fire and damage to equipment:

1. Remove any combustible material from vicinity of the fire (a fire cannot burn without fuel).

2. If the fire is electrical in nature, cut the power to the affected area by pulling the appropriate circuit breaker.
3. Hose down nearby structures (a fire cannot start unless kindling temperature is reached).
4. Remove any equipment which can be moved from the area.

EXPLOSION

The possibility of explosion in a water reclamation plant is quite remote; however, it does exist. There are various pieces of pressure equipment which could explode. In the event of such an occurrence, the operator should remove the source of high pressure by either closing the proper valve or shutting down the proper equipment providing the pressure. Notify supervisor immediately.

PUMP JAMMING

Due to the source of the influent for the tertiary plant, the possibility of a pump jamming is remote, but possible. If a pump does jam, shut the pump off and close the gate valve on the suction side of the pump. Allow the pump to drain, remove the inspection plates on the suction side of the pump and remove the jammed material, if possible. If this cannot be done, notify your supervisor who will report the condition to the maintenance section.

FREEZING.

The Lancaster area is subject to freezing temperatures in the winter. Should a shutdown occur for an extended period at night it is possible that the pipes will freeze up. One method of rectifying this problem is to heat the piping system with either an electric heater or gas torch (use extreme caution) until the ice thaws and the equipment will run. The water will not freeze if it is circulating at normal flows.

EQUIPMENT BREAKDOWNS

Equipment breakdowns can occur whenever machinery is present. Breakdowns are caused by excessive wear, faulty parts, or overloading. Failure of any mechanical process equipment at the tertiary plant will force the shutdown of the plant until the equipment is either repaired or replaced.

PROCESS FAILURE

In general terms "Process Failure" could be defined as "any condition which reduces the efficiency of the plant such that the Water Quality Control Board Requirements are not being met." Therefore, to be aware of an upset, the operator must be thoroughly familiar with the Water Quality Control Board Requirements which this plant must meet. An up-to-date copy of these requirements are on display in the control building at all times. Also, requirements for tertiary plant discharge set down by the County Engineer and the Health Department must be met. Should a process failure occur, appropriate monitoring systems and control tests should be checked for abnormalities which may indicate the cause of this upset. During the upset the plant may be operated, but the effluent must be recycled to the District 14 Plant's influent wetwell until the effluent meets the discharge criteria.

PERSONNEL INJURY

General

Personnel injury is always a possibility in a treatment plant; however, this does not mean that an injury must happen. Some general principals are suggested below to help keep the incidence of accidents to a minimum:

1. Always wear safety hard-hat while on plant grounds.
2. Whenever working in hazardous areas stay ALERT.

3. Use the safety equipment provided for the job.
4. Don't ever take the attitude "it will take too much time to get the safety equipment". Your supervisory personnel take the attitude that taking the time to obtain the proper safety equipment and planning a safe method of attacking the problem is time well spent when it results in safe working conditions and injury free operations.

A safety manual has been prepared and issued to all operating personnel. The regulations set forth in this manual were designed to obtain safe working conditions and should be strictly adhered to.

In the Event of Injury to Personnel

Medical services may be obtained at:

Antelope Valley Hospital
1600 West Avenue J
Lancaster, California
Phone: (805) 948-4577

NOTIFICATION LIST

In the event of occurrences listed below, the personnel or agency listed should be notified.

1. Interruption of power delivered to plant, hazard to Edison equipment or accident to Edison employee: Southern California Edison Company, Lancaster (805) 942-9531
2. Emergency in Chlorine Storage Area:
   a. Your supervisor
   b. Fire Department Rescue Squad, Lancaster (805) 948-2631